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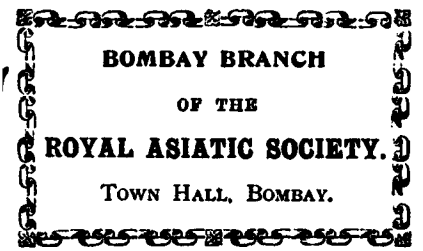

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PREFATORIAL.

IT has been freely stated during the past few years, that microscopy does not attract the studious amateur in the manner that it is entitled to do, and there is superficial evidence of such a state of things in the fact that several journals devoted to the subject have ceased to be published, and columns in scientific journals have been closed for lack of interest. Added to this, many societies originated for purely microscopical work have gradually become transformed into photographic and natural history clubs, or have closed their doors and disposed of their collected instruments and materials.

This is not altogether a hopeful state of things, but we emphatically repudiate the idea that the amateur microscopist is a diminishing quantity. Rather is it that microscopy has been raised to a higher level and is pursued in a more scientific spirit than it used to be. The work oftentimes done, though not such as to arouse enthusiasm at a society's meeting—it is often just the reverse in effect—or of a character that would make popular reading, assists materially to a better understanding of Nature's mysteries and wondrous laws.

There is immensely more printed matter concerning microscopical investigations than ever before, but it is diffused through the numerous scientific and medical publications. Specialisation has induced this, and it is only natural that the man who is putting his best efforts into some one branch of research, be it medical, geological, botanical, or entomological, should desire his reasonings and conclusions to be submitted to those who are similarly interested, through the medium of a society devoted to a particular subject, rather than through a cosmopolitan microscopical society or journal.

The microscope has become so extensively used for educational, medical and professional purposes that to a large extent amateur efforts are overshadowed, but it cannot be disregarded that the pre-eminent position which the microscope occupies amongst instruments of precision has been almost entirely due to the original theoretical and practical work of enthusiastic amateurs. Men having scientific tastes who pursue microscopy as a hobby are better able to think out improvements in detail than those who employ the microscope for purposes of necessity.

Microscopical work in laboratories has been frequently carried on with instruments of inferior calibre, and although highly meritorious and original research may have been accomplished with but poor means it is becoming increasingly recognised that a good microscope used in an intelligent manner, enables work to be done with increased facility and accuracy, and the more enlightened of the professors and demonstrators are eager to avail themselves and place at the disposal of their students each practical improvement that is brought forward. The laboratory worker can teach the amateur much that would be of assistance and interest to him, and the amateur can be and is a distinct aid to the laboratory, it would, therefore, be advantageous if he could become more fully acquainted with its necessities. For instance, the objectives that are most capable of resolving diatoms are not always the best suited for bacteriological and general histological examinations, and those which are most in favour amongst professional workers, apart from the question of price, are not those which would be considered the finest for the purpose by the "brass and glass" amateur. There is a constant cry for a "flatter field," and for lenses that will stand a fairly large cone of illumination without becoming hazy; to obtain these qualities a lens of small aperture is constantly selected and used. The amateur would render a great service to the laboratory if he could induce opticians to embody these virtues in a lens of moderately proportionate aperture to its power.

It has been represented to us that an Annual which gave details of work in various departments of research, in which the views, difficulties and achievements of different investigators could find expression, would be of value and utility to the working microscopist; it would also be the means of bringing the professional and amateur together to mutual advantage, and might tend to the further development of processes and instruments. We have had presented to us in this volume articles from all classes of workers, theoretical and practical. Cause and effect can be traced in "The elementary theory of the microscope": the latest additions to the enormous variety of instruments which are constantly being introduced are reviewed in "The Microscope in 1897," and a glimpse is obtained of the work which is in progress from a perusal of the various other articles.

We desire to acknowledge our great indebtedness to the contributors of the various papers, every one of whom is a master of the subject on which he has written.

The very cordial co-operation that has been accorded to us in the preparation of this first issue and the expressions of approbation that have been received concerning it, lead us to believe that it will be found acceptable and conduce to a keener and more consolidated interest in microscopical work, and that next year an annual equal if not superior to the present compilation may be put forth.

B. DIPHTHERIÆ.

Fig. 1.

Fig. 2.

B. DIPHTHERIÆ, *var. Sheath.*

Fig. 3.

Fig. 4.

B. OF HOFFMANN.

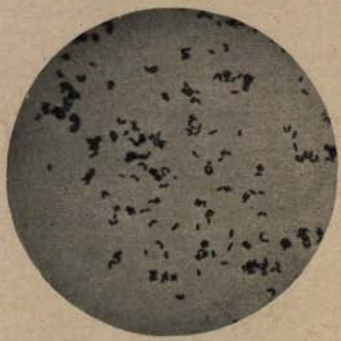


Fig. 5.

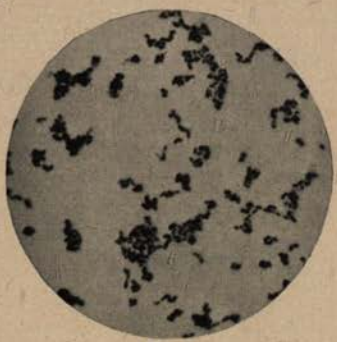


Fig. 6.

B. XEROSIS.

Fig. 7.

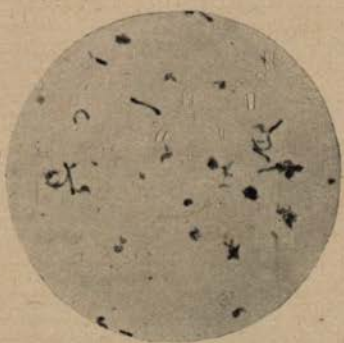


Fig. 8.

THE DIPHTHERIA GROUP OF BACILLI; SOME POINTS IN THE MORPHOLOGY OF ITS MEMBERS.

Jno. Eyre, M.D.

IN 1883, Klebs first described a bacillus he had found in microscopic specimens prepared from the membranous exudation upon the throats of diphtheria patients. Löffler, in the following year, isolated this bacillus, cultivated it upon artificial media, and by means of experiments upon animals proved that it was the actual cause of diphtheria; and so closely are those two names associated with the organism in question that it is frequently spoken of as the Klebs-Löffler bacillus. Their observations were soon confirmed by other workers, notably Roux and Yersin in France; Klein in England; and after a longer interval by Abbot and Welsh in America.

The method of demonstrating the *Bacillus diphtheriæ* in the membranous exudation of cases suffering from diphtheria, may be summarized as follows. A platinum wire loop, mounted in a handle of glass or aluminium, is sterilized in the flame of a Bunsen burner, and then rubbed over the surface of the membrane. The charged loop is gently smeared over the slanted surface of sterile animal blood serum, which has been solidified in a test-tube by prolonged exposure to a temperature of about 80° C. Then without recharging, a second, third and fourth serum tube is "inoculated" in the same way. (Instead of, and I might say in preference to, the platinum loop, one may use a six inch length of soft iron wire, having some absorbent cotton-wool twisted round one end, and kept in a stout test-tube plugged with cotton-wool, until required—the whole apparatus having been previously sterilized by an exposure of forty-five minutes to a temperature of 150° C.)

The tubes are now placed in an incubator regulated at the body temperature, *i.e.*, 37·5° C. After an interval varying from eight to twenty hours (generally the latter, as no growth is usually visible to the naked eye under eighteen hours), the macroscopic examination of the surface of the medium will show the presence of colonies, small, numerous and lying closely together in the case of the tubes first inoculated; but larger, fewer and more widely separated in those planted last.

The growth is not usually a pure one, that is to say, the colonies represent more than one species of bacterium, and consequently vary more or less in their naked eye appearances, with regard to size, shape and colour, etc. Microscopically the organisms commonly found associated with the *B. Diphtheriæ* in the membrane are *cocci*, either in masses (*staphylococci*): in pairs (*diplococci*): or chains (*streptococci*): various kinds of bacilli, and yeast cells.

In seeking the *B. Diphtheriæ* advantage is often taken of the fact that upon blood-serum it grows better and more rapidly than its associates; and a tube planted from diphtheritic membrane will sometimes, at the end of eighteen hours' incubation, appear to contain a growth of the Klebs-Löffler bacillus only; although if examined after another six or eight hours, a luxuriant growth of many different bacteria will probably be found.

Now although the naked eye appearance of the colonies of the *B. Diphtheriæ* is to a certain extent characteristic, there are many other organisms, notably those included in the same group, and some of the staphylococci, which produce similar colonies, and a large amount of experience is necessary in order to differentiate them with any degree of accuracy; still the following description will serve as an indication of the kind of colony to which special attention should be given and of which microscopical examinations should be made.

COLONIES OF THE B. DIPHTHERIÆ UPON BLOOD SERUM.—Large, roughly circular, moist, shining, opaque, greyish-white plaques, of one to four mm. diameter, slightly raised above the surface of the medium, and more opaque and heaped up in the centre than at the periphery. The edge is irregular and notched and the surface coarsely granular.

The next step is to make stained specimens, "covered-slip" preparations, from likely colonies; these must be examined microscopically, using the one-twelfth-inch oil immersion lens. Colonies which under these conditions are found to consist of any of the varied forms of cocci are to be neglected, and only those composed of rod-shaped organisms need be considered.

Having briefly indicated the method of conducting the early stages of the bacteriological investigation of a case of diphtheria, we have now reached a point where it only remains to say whether the particular bacillus in our preparation is the Klebs-Löffler bacillus or not; but so far from our difficulties being over, an entirely fresh set now confronts us. The diphtheria group includes several varieties of bacilli which morphologically closely resemble each other, but vary greatly in their potentiality for evil when introduced into the human frame; and again, the diphtheria bacillus itself appears under at least two forms, equally virulent, but very dissimilar in their microscopical characters.

The relationship existing between these bacilli, imperfectly understood even now, and still more obscure twelve years ago, gave rise to much confusion—a confusion worse confounded by the system of nomenclature then adopted. For instance, Roux soon detected an organism in the throats of patients suffering from diphtheria, and sometimes in healthy throats, as well as in other situations, which could not be distinguished from the *B. Diphtheriæ* either by its morphological or cultural characteristics, but which had entirely lost its pathogenicity, and its introduction into the living body was not followed by any ill effects; consequently the name pseudo-diphtheria bacillus was suggested for it.

In the light of later knowledge, this name would appear to be inaccurate as well as ill-advised, for we know now that many pathogenic bacteria will, under certain conditions give rise to a race that is harmless, and to such we apply the term "non-virulent." Reasoning from analogy this descriptive prefix would seem more applicable to the present case than the term "pseudo," so long in vogue. The virulent variety of the *B. Diphtheriæ* was called by early workers the "long" form, and the one designated below var. "sheath," the medium form. To complete the simile the name "short" form was applied to an organism, belonging to the same group, which von Hoffmann isolated, about the year 1885, from the mucus of cases of chronic catarrh of the nose. More recently, however, there has been a growing tendency to apply the name of its discoverer to this last bacillus.

The next member of the group, the Xerosis bacillus, was isolated by Neisser from a foul ulcer of the leg, and has been found since by many observers associated with diseased conditions of the eye. It is only lately, however, that its life history has been fully worked out. It is perfectly innocuous, but its remarkable similarity to the *B. Diphtheriæ* clothes it with an importance hardly warranted by our present knowledge of the *rôle* it plays in the economy of nature.

Before discussing the microscopical appearances of these bacilli a few words with regard to the staining reagents, may not be amiss. Undoubtedly the stain which has, in my hands, given the best all-round results is carbolic methylene blue, or more shortly C.M.B., prepared in the following manner :—Place about 10 grammes of methylene blue (Grübler) in a well-stoppered bottle, and add 50 to 60 cubic centimètres of absolute alcohol ; allow it to stand for three or four days, occasionally shaking the bottle vigorously. At the end of this time the resulting saturated alcoholic solution of the stain is filtered through Swedish paper into a small drop-bottle ready for everyday use. To the undissolved stain in the mixing bottle more alcohol is added and forms a reserve stock from which the drop bottle may be replenished.

Methylene blue, it may be remarked, improves with age, and when used for the purpose of staining the diphtheria bacillus, every month that it is kept increases its value for demonstrating the phenomenon known as metachromatism. By the side of the M.B. bottle, upon the bench, one keeps a larger bottle containing a supply of a 5% solution of carbolic acid. When about to stain a cover-slip film, five or six drops of the M.B. are dropped into a watch-glass, and sufficient carbolic solution added to fill the glass. The C.M.B. stain thus prepared is taken up in a pipette (provided with an indiarubber cap), run on to the surface of the film and allowed to remain there for about two minutes. The coverslip is then thoroughly washed in water, dried and mounted. A small rubber "change mat," such as tradespeople use upon their counters to receive money, makes an even more convenient rest for the coverslips than Cornet's forceps and has the additional advantage of taking several at one time.

Löffler's blue is also a handy stain, but to my mind does not give such good results as the stain above described.

Saturated alcoholic solution of gentian violet is also useful. This stain appears to swell the bacilli, an effect probably due to the fact that it stains the whole of the bacillus, including the thickness of the sheath, very evenly.

Carbolic fuchsin, prepared in a similar manner to the C.M.B. (*vide supra*) is an excellent stain for the purpose of showing up involution and degeneration forms in old cultures. For this particular purpose, too, polychrome methylene blue (Grübler) is extremely useful.

We propose to describe the morphology of the various members of the diphtheria group, as illustrated by blood-serum cultivations which have been grown at 37·5°C.—taking first a young culture 16 to 18 hours old, and then examining the same culture after another 54 to 56 hours' sojourn in the incubator. In order to avoid confusion the nomenclature adopted for our present purpose is as follows:—

1.—*B. Diphtheriæ.*
2.—*B. Diphtheriæ*, var. " sheath."
3.—*B. Diphtheriæ*, var. " non-virulent."
4.—B. of Hoffmann.
5.—*B. Xerosis.*

1.—B. DIPHTHERIÆ

Eighteen-hour blood serum cultures (fig. 1).

The *B. Diphtheriæ* occurs as straight or slightly curved rods, varying in length from 2 or 3 μ — 6 μ; and in breadth from 0·5 μ — 1 μ, the ends rounded, and frequently one or both ends slightly swollen. The arrangement of the bacilli in the field is extremely irregular and confused, and has been compared, not inaptly, to Chinese heiroglyphics. In unstained specimens, examined by the hanging-drop method, the bacilli are found to be motionless, and the above-mentioned swollen points appear bright and glistening. (For some time these refractile points were supposed to be true endospores. Further investigation, however, has shown that the *B. Diphtheriæ* will not stand exposure to a temperature of 58°C. for more than ten minutes—proof positive that it is not capable of spore formation; and in point of fact, reproduction takes place by fission only). When stained, these points are found to take the dye most deeply.

Although in some specimens of the *B. Diphtheriæ* of this age, the protoplasm stains evenly and equally throughout the length of the bacillus, still many show what is termed "segmentation," or in other words, that the cell protoplasm has in some situations become altered in its constitution so that it no longer takes the stain well, and we consequently have bacilli appearing as short chains of dark round or oval beads, separated from each other by unstained or faintly stained irregular intervals, and the whole enclosed in a well-developed and plainly visible sheath. (The accompanying " schematic " diagram of the bacilli will explain my meaning.)

Diagram A.

Seventy-two-hour blood serum cultures (fig. 2).

If this same cultivation be examined again after three days' incubation at the body temperature, one finds but few individuals resembling those described above, for the Diphtheria bacillus is an organism that quickly degenerates, and what are termed "involution" forms now preponderate.

These forms vary greatly in shape and size, some are short, deeply staining pear-shaped bodies; others, squat forms showing alternate bands of darkly-stained and unstained protoplasm, and resembling a spinning top; many have a long slender stem and a greatly swollen club-shaped extremity; some again look like overgrown cocci, and are probably the large oval ends of some of the club forms, escaped from the sheath (Diagram B). Many of the bacilli, more closely resembling the young forms in shape and size, are either but faintly stained or have not taken up the stain at all. All those forms that are stained (especially

when matured C.M.B. has been used) show more or less metachromatism, and this feature is particularly well marked in the swollen club-shaped extremities.

2.—B. DIPHTHERIÆ, VAR. "SHEATH."

Eighteen-hour blood serum cultures (fig. 3).

In young cultures this organism occurs as a straight, or very slightly curved rod, tapering to a fine point at either end, of about the same size as the ordinary Diphtheria bacillus grown under similar conditions. Here the resemblance ends, for the segmented forms and those showing terminal enlargements are conspicuous by their absence.

Diagram B.

In the variety now under consideration, that portion of the cell protoplasm which takes the stain most vividly, is aggregated into an elongated lozenge-shaped mass, situated in the centre of the bacillus, and having its long axis in that of the bacillus. The unstained or faintly stained and therefore presumably altered protoplasm, surrounds this central mass, and enclosing all will be observed a well developed sheath, which usually, although not invariably, takes the stain right up to its pointed extremity, somewhat less deeply than the central body.

By some observers it has been stated that the "sheath" variety is much shorter than the ordinary Klebs-Löffler bacillus, and if one measures the central deeply-stained mass *only*, this is correct. If, however, the organism is measured from point to point of its sheath it is found to be of the same size, or, if anything, a little longer than the *B. Diphtheriæ*.

Multiplication takes place entirely by fission, a remark which applies equally to all the members of the Diphtheria group. The whole process may be watched in a hanging-drop cultivation, binary division being completed in about thirty to forty-five minutes, the time varying with the temperature. In stained specimens, too, one may often notice a narrow unstained horizontal line, or even a broader space, marking the short axis of the central lozenge-shaped mass, and converting it into a couple of triangles. This marks the point where division would have taken place if development had not been arrested. Very rarely some segmentation of this central mass may be noted (Diagram C).

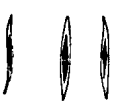


Diagram C.

Seventy-two-hour blood serum cultures (fig. 4).

Cultivations at three days, like those of the *B. Diphtheriæ*, from which they can hardly be distinguished, show numerous involution forms, and stained specimens are characterized by marked metachromatism. The club forms are quite as numerous, the only difference being that the short swollen forms are less common and the individual bacilli may appear somewhat more slender. The well-marked sheath, so prominent a feature of the younger cultures, can hardly be detected.

A few words are necessary as to the relationship existing between the *B. Diphtheriæ* and the "sheath" variety. Although it is rare* to find a cultivation from a diphtheritic throat, to consist solely of the sheath variety, it is also rare for one to be unable to find some sheath forms among the numbers of ordinary Klebs-Löffler bacilli, in such a preparation. If a tube of melted agar-agar is inoculated from a single colony of the *B. Diphtheriæ* (which microscopically does not appear to contain any sheath forms) and a "plate" cultivation poured in the usual way, incubated at 37·5°c., and each colony appearing at the end of, say, twenty-four hours, examined separately, at least one, sometimes many of them, will be found to consist of the sheath variety only. This variety may be sub-cultivated upon blood serum for many generations, and will remain unaltered; but if it is planted upon alkaline potato and grown for some days, and then transferred to blood serum, it will be found to have reverted completely to the ordinary type, and the sheath, instead of being the most prominent feature of the organism, has now to be carefully sought for before its presence becomes apparent.

3.—B. DIPHTHERIÆ, VAR. "NON-VIRULENT."

Morphologically this organism is identical with the ordinary *B. Diphtheriæ*, only differing from this bacillus in its want of virulence; the microscopical characters described under 1 therefore apply to this variety also.

4.—B. OF HOFFMANN.

Eighteen-hour blood serum cultures (fig. 5)

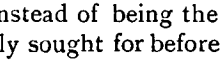


Diagram D.

This organism occurs as a short rod-shaped or oval bacillus 0·8μ — 1·5μ in length, and from 0·3μ — 0·5μ in breadth. The ends are either both rounded, or one rounded and the other tapering to a point. Unlike the *B. Diphtheriæ* there is a certain definite arrangement of this bacillus to be noted in stained cover-slips. It is usually disposed in pairs, either two organisms placed end to end, or side by side; frequently one finds a combination of these, that is to say, small groups of four. Hoffmann's bacillus usually has but one darkly staining "aggregation" of protoplasm, roughly triangular or perhaps conical in shape, with its base closely applied to one end of the bacillus, and a very faintly stained interval between its apex and the sheath. More rarely one may detect an extremely narrow unstained line dividing the aggregation into two portions. The enclosing sheath, it should be remarked, is as a rule, badly defined and takes the stain faintly (Diagram D).

Seventy-two-hour blood serum cultures (fig. 6).

In preparations from old cultures, numerous involution forms are present, and these very seldom assume the club form so common with the *B. Diphtheriæ*. Short oval, egg-shaped, and irregular spherical forms are present, together with many resembling the younger individuals, but staining very badly. Many of the individual bacilli reach a considerable size, but the increase appears to affect the breadth only, never the length of the organism. Metachromatism is rare.

* An experience of between 3000 and 4000 cases of suspected Diphtheritic throats, would lead me to give the proportion of cultures where the sheath variety occurs unmixed with the ordinary *B. Diphtheriæ* to those where it is absent or greatly outnumbered by that organism as about one to seven or eight.

5.—B. Xerosis.

This bacillus when first planted from the human subject upon blood serum, does not grow rapidly, and its colonies rarely become visible to the naked eye under thirty-six to forty-eight hours. Subcultures upon serum, however, grow well in eighteen to twenty-four hours and preparations made therefrom may be described as follows :—

The bacilli are generally straight or very slightly curved, often occurring in pairs, attached either at a slight angle, or in the same straight line. The length is about 1·5μ and the breadth 0·6μ. The characteristic grouping of the organism is in small clumps or rosettes of 15 to 45 individuals. The bacilli stain well and a fair amount of segmentatation is to be noticed. In some a distinct swelling of one extremity has taken place, and definite club forms are to be seen (fig. 7).

Seventy-two-hour blood serum cultures (fig. 8).

At this date the Xerosis bacillus so closely resembles the Klebs-Löffler bacillus as to be practically indistinguishable from it. The individuals are clubbed, or segmented, or both forms may be seen in one and the same bacillus. Short pear-shaped and irregular bodies, transversely striated are noticed; and metachromatism is a very common feature. The grouping of the bacilli into small bunches is, however, fairly constant.

In conclusion it is necessary to mention the most recently described member of the group, the *B. coryzae segmentosus*, an organism isolated by Dr. Cautley from the nasal mucus of cases of severe "influenza cold," and evidently considered by him to be the specific cause of this condition. Personally, I have been unable, up to the present time, to isolate specimens of this bacillus, but from the published descriptions and the admirable photo-micrographs which accompany the description, it is evident that the microscopical appearances of the bacillus closely resemble those of the Xerosis bacillus in the early cultures upon Agar-agar, but with increase in age more nearly approach those of Hoffmann's bacillus. No mention is made of the characters of the bacillus upon blood serum, so that it is only fair to conclude that this medium was not used by Dr. Cautley in the course of his investigations.

PHOTO-MICROGRAPHY.

J. W. Gifford.

TO write an article on the microscope, even if one confines oneself to "brass and glass," is rather a large order. Let me therefore assume that my readers already know something of that instrument, and console them by saying that I have only a few things to say about photography with the microscope, and so, while warning them that they may have heard most of these things before, go on at once to my subject.

For photography with the microscope, a good firm stand is indispensable, and nothing is better than Messrs. Powell & Lealand's splendidly rigid instru-

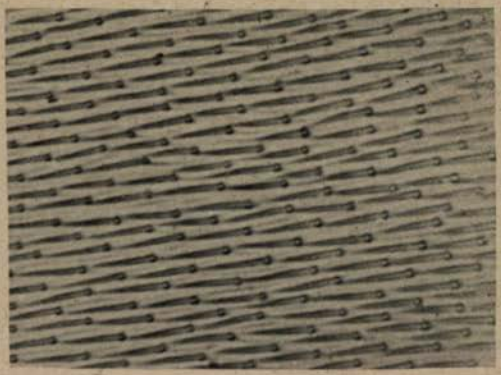
ment. But it by no means follows that good work cannot be done by something much more modest. Swift's "Challenge" is the stand with which the illustrations shown on opposite page were made. A binocular instrument is of course unnecessary, but the tube should slide and be graduated, so that it may be set at any length from 250 to 160 millimètres (say, from 10 to 6 inches). I have so often found that a really good object-glass will only work with the short tube, especially a magnificent oil-immersion made for me by Zeiss, which was quite inaccessible until I had my tube altered.

The most important point about the stand is the fine adjustment, which should work smoothly, and with as little "loss of time" as possible. Messrs. Powell & Lealand in their first-class stand bring this about by the use of a long lever arm on the free end of which a delicate screw works. Other makers have adopted other adjustments, a very good one among them being Campbell's differential screw.

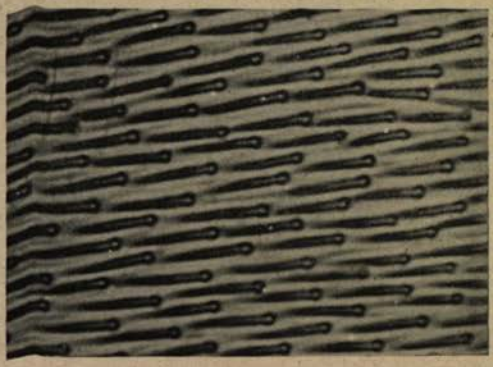
The stage may be of the horseshoe form with sliding-bar as in the Nelson-Curties model made by Mr. Baker. This instrument also has the Campbell fine adjustment, and when provided with mechanical motions for the substage, is the most satisfactory instrument of the cheaper sort I have seen. For photographic purposes the microscope must of course be used horizontally, unless an eyepiece camera or vertical camera is used which I do not recommend. When purchasing, it is therefore well to ascertain that when inclined, the tube is approximately level, and if not to have the stop readjusted.

So many forms of photo-micrographic apparatus are in the market that one hesitates about going into details. Let it suffice that they, most of them, consist of some form of long-extension bellows camera arranged to slide in a groove on a table and attached to the microscope tube by a sleeve or other device for making a light-tight connection. A long rod actuates an arrangement for focussing from the back of the camera. But perhaps the most simple and satisfactory arrangement of all is the following, for which an ordinary photographic dark-room is almost all that is required.

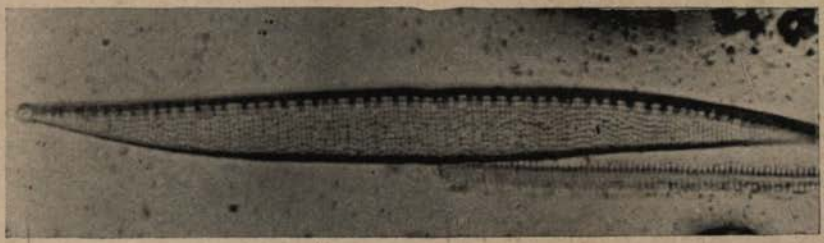
A hole should be made in one of the walls which often happens to be a wooden partition, and this hole may be fitted with the flange of an ordinary photographic lens. Having removed the lenses and put them away, for they are of no use for our purpose, the tube can then be screwed in and connected to the tube of the microscope, which should be placed on a table outside, by the cloth sleeve. The table must of course be pushed up close. A disc of fairly limp blackened cardboard with a hole in it just large enough to receive the end of the eyepiece, and of sufficient diameter to project well over the edge of the tube in the wall, is a good substitute for the sleeve and takes less time to make. Another small hole in the wall, well "bushed" with felt, admits the focussing rod, and the whole thing is complete. All that remains to be done is for the operator to provide himself with another table of the right height, a block of wood with a groove in it, which will slide about on the table, a white card and a photographic plate, and having arranged his object in the microscope, and taken these things into the dark-room, to shut himself in. He then focusses accurately on the white card having fixed it upright by means of the groove, carefully removes it and puts



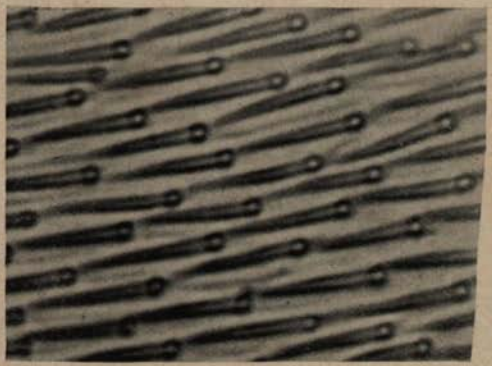
1—Podura scale × 1350, Zeiss 3 mm. apochromat 1·4 NA., lamp flame and methyl-green screen. 3 hours.



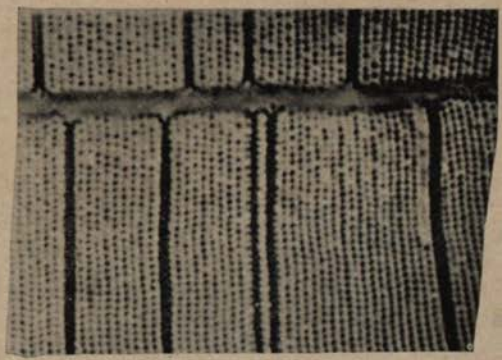
2.—The same × 1944 Powell's 1-10-inch semi-apochromat 1.5 NA. Light and screen as above. Exposure, 7 hours.



4.—Nitzschia Curvula × 1350, Zeiss 3 mm. apochromat. Limelight and signal-green glass. Realgar mount.



3.—As above × 4860, but Powell's achromatic 1-25-inch of 1 38 NA. and limelight. Exposure, 7 minutes.



5.—Surirella Gemma. × 1350 and as above.

To face page 16.

in the photographic plate without moving the block, and sits down until the exposure is over. If the exposures are likely to be long as with the high powers, it is easy to arrange a curtain over the door of the dark-room and to darken the room outside, so that the operator may get out and go in again without fogging the plate. This plan is a very simple one, and I am surprised that it is not more frequently put into practice, especially as most microscopists who photograph generally have a dark-room ready at hand. Provided the room is long enough there is practically no limit to the size of the plate that may be covered, whereas in the ordinary way one is tied down to the size of one's dark slide.

The optical part of the microscope may be as good, or, I was going to say, as bad as you like, for provided certain precautions are taken with the illumination, good results may be obtained with quite third-rate objectives. But apochromatics by first-rate makers such as Zeiss, and Powell and Lealand give a very much flatter field of view than the cheaper objectives and for this reason and the larger available aperture are well worth their apparently high price. Of these a 1-inch, $\frac{1}{4}$-inch and $\frac{1}{12}$-inch oil immersion embrace all that is generally required. The $\frac{1}{12}$-inch should be of 1·3 N.A. which is more convenient to work with than 1·4 N.A. I have in my possession objectives of 1·4 and 1·5 numerical aperture, but have found no great advantage attend their use. They are extremely costly.

Except for the purpose of finding and adjusting the objective no eyepieces are absolutely necessary, but it is far more convenient to use one of the two projection eyepieces usually sold, and highly desirable if the objectives are apochromatics, as these lenses depend for their complete correction on the eyepiece. Of these projection eyepieces Zeiss (other makers have, I believe, followed) makes a low power, which magnifies the image given by the objective three times, and a higher power magnifying six times. The low power is generally recommended for use whenever possible, avoiding the high power unless extreme high amplification is absolutely necessary. I have, on the contrary, found no difficulty whatever in using the higher power, and generally prefer it, one can for instance use a $\frac{1}{10}$-inch objective with it, instead of a $\frac{1}{20}$-inch with the lower power, and in this way obtain a more even illumination and a flatter field provided the $\frac{1}{10}$-inch has as great an aperture as the $\frac{1}{20}$-inch. The theoretical objection to the high power eyepiece is that the curves of its lenses are steeper, which among other disadvantages causes a greater loss of light. It appears to me, however, that this objection would apply to the object-glass as well.

For substage apparatus there is nothing better than Messrs. Powell and Lealand's apochromatic condenser with an aperture of about ·95 N.A. It will perhaps be said that such an aperture is comparatively small, but, as I shall show, this is of no disadvantage. The fact is that an objective that will work with an aperture of 1·00 N.A., stands at about the top of the tree as regards the possibilities of lens construction up to the present time. An objective of larger aperture when illuminated axially, must be limited to this, by stopping down, or will give a woolly image. This is due to the want of success on the part of opticians, in centreing light pencils of greater obliquity to the axis. I would refer those who would like to follow this further, to the last edition of Dr.

Carpenter's "The Microscope," in which Dr. Dallinger and Mr. Nelson have expounded this and Professor Abbe's Diffraction Theory at some length. It is sufficient for my purpose to say, that these researches have conclusively proved that all results obtained by any other than strictly axial illumination are utterly unreliable, and that although oblique illumination may give certain appearances not otherwise obtainable, we have reasons for believing them to be mere effects. An oil-immersion condenser, therefore, of 1·3 N.A. and upwards is of no use, except for studying these effects. But resolutions of difficult test-objects comparable with the most difficult formerly obtained by oblique illumination, may now be made by mounting the test-object, such as a diatom, in a medium of high refractive index. Of these, phosphorus is the easiest to work with, but harbours unpleasant possibilities, especially when a bit happens to get under one of the fingernails of the operator and is lost sight of for the time. It is almost sure to go off some short time afterwards, and his pain and astonishment are great. Phosphorus mounts are also always spoiled by working with direct sunlight, which is occasionally desirable. I much prefer realgar, which has an even higher refractive index, or rather a mixture of realgar with sulphur, which is perhaps strictly speaking a higher sulphide of arsenic, intermediate between realgar and orpiment. It is prepared by heating together equal quantities of clear red realgar and stick brimstone (flour sulphur is apt to be full of dust). In order to prepare the mount a drop of the solution containing the diatoms must be dried on a very thin cover-glass and the diatoms then burnt into the glass by passing it, diatoms uppermost, through the flame of a spirit lamp. A small piece of the medium is then placed on the glass slide which is carefully warmed in the same way by passing to and fro through the flame, until the medium melts, and while both are still in the flame of the lamp, the cover is turned over and carefully lowered until contact is made with the medium. As soon as it has spread out to the edges, a clip must be put on, or the medium will crack off in cooling, which must take place very gradually. The best thing is to put the mount still hot, into a small tin box, previously warmed, and place the whole in a vessel containing boiling water and put aside to cool. The water must, of course, not touch the mount. There will be many failures, but when a good mount has been made, it will be well worth the pains taken. This medium is very yellow, but as will be presently seen, this is no objection.

For examining and photographing fresh tissues, minute dissections, etc., I have found nothing so good as glycerine.

As regards other apparatus, a good bull's-eye to concentrate the rays from the lamp on the substage condenser is almost a necessity. By this means the entire field of view is easily filled with light. The best is Mr. Nelson's aplanatic bull's-eye, which is generally made of glass. But Mr. Nelson has very kindly computed a quartz aplanatic condenser especially for me, and I have found that exposures have, thereby, been much shortened. Quartz is considerably more transparent than glass even for the visible rays, and I am unable to speak too highly of the performance of this quartz doublet.

If the finest results, even with apochromatic objectives, are sought, it is well to use a light filter. For the yellow realgar mounts a piece of signal green glass

(or peacock green) is all sufficient. Such an arrangement provides for light which, analysed by a prism, gives a single band of light in the green. Of course to work with this a green sensitive plate must be used. Lumière's yellow-green sensitive plates are very good for the purpose. For objects mounted in water-white media it is better to use a methyl-green screen. Malachite green answers quite as well, but a slightly longer exposure is necessary. The most simple way to prepare one temporarily is to dissolve the dye in water and fill with it a glass zoophyte trough such as that for use on the stage when the microscope is placed horizontally. In the trough, and standing in the coloured water, is placed the piece of signal-green glass before referred to, and this has the effect of cutting off some extreme red rays which otherwise find their way through the dye and upset the focus. After focussing the glass may be taken out. It is well to do this as much more light gets through without it. But if such a screen is required permanently it is much better to build up a cell on signal-green glass with a metal ring and gold size, as for liquid mounts, and seal in the liquid permanently. In this case it is better to use glycerine instead of the water (see *Journ. R. Micr. Soc.*, 1894, pp. 164-7; and 1895, pp. 145-7). The blue and the violet aniline colours may be used similarly, but I do not recommend them unless with specially corrected objectives. By the use of these screens and photographic plates sensitive to the rays they pass, almost as good results may be obtained with object-glasses of the cheaper sort (ordinary achromatics) and having inferior colour corrections, as with the most costly, provided they are fairly free from spherical aberration.

The best source of light is undoubtedly the limelight from a mixer jet. A water trough must be provided to eliminate the heat rays. With this, an exposure of ten minutes, even with a $\frac{1}{20}$-inch objective is the very outside necessary, and such a power is really never needed. By using the limelight the risk of alterations of focus from temperature changes and vibration is minimized. The bright spot on the lime must be focussed by the substage condenser on the object without the bull's-eye, which should be afterwards interposed. It is hardly necessary to say that the eyes must be protected by using smoke-tinted spectacles while focussing, or they will be injured. The simple apparatus for producing the gases now placed on the market by the "Portable Limelight Syndicate," will probably prove invaluable for photo-micrography, affording as it does, an ever-ready means of obtaining the light without any previous preparation and without the use of the cumbrous and dangerous cylinders of compressed gas.

But an ordinary petroleum lamp such as Rowatt's "Anucapnic" with a wick about $1\frac{1}{2}$ inches broad, used flame end on, answers most purposes, if carefully focussed on the object in the same way, and if, like the writer, you have a cellar in the country where there is nothing to fear from vibration. With this lamp, the quartz aplanat, and a methyl-green screen, I have made exposures extending over as long a time as nineteen hours and obtained quite sharp negatives. If the temperature changes are likely to interfere, I obviate these by the use of a constant temperature apparatus consisting of the ordinary Bunsen regulator attached to the gas, of which a jet is kept burning.

The photographs facing page 16 were all obtained by strictly axial illumination.

A FEW WORDS ON RED MITES FOUND IN FRESH WATER.

By Chas. D. Soar.

GIVEN a good microscope and an easily accessible pond, and what a field for research is still open to the student in natural history! What a lot of Nature's little secrets are yet left unread! In the vicinity of a good all-the-year-round pond a small local club would have sufficient material to keep it going always. If the club did not number many members, the pond would furnish enough different subjects to allow each member to study a different group. For instance, one member could take *Rotifera*, another the *Entomostraca*, another the Diatoms, etc., etc., and they would sometimes find their independent studies of great mutual assistance. Not a few of the great army of pond hunters (or puddle rakers as they are sometimes called in derision by the unthinking) are looking forward to the formation of a Fresh Water Biological Station in England, on a similar plan to that at Plön in Holstein, Germany. When this takes place, which we all hope it will, we shall be in a better position to study the life history of various forms of aquatic life of which we are now so ignorant.

Now there is one form of pond life in particular to which I wish to draw attention, and that is the *Hydrachnidæ* (Fresh-Water Mites). They are very beautiful both in colour and form, and they are fairly common, but very few pond hunters, if they take one when collecting, know more about it than that it is a member of the acarina. I have often asked microscopists when they have been collecting to kindly save me any water mites they might find of a particular genus, but they invariably answer "I only know the common red one," and are very much surprised when they are told that there are between twenty and thirty distinct species of red mites found in fresh water in England.

In England we know of twenty-six distinct genera, and seventy-two identified species, only two of which have been named by Englishmen—*Thyas petrophilus* (Michael) and *Arrenurus novus* (George). The red mites which I know, are distributed as follows: *Arrenurus* three, *Piona* one, *Nesæa* five, *Limnesia*, three, *Hydrachna* two, *Hydrodroma* two, *Marica* one, *Diplodontus* one, *Eylais* one, *Bradybates* one, *Limnochares* one, *Thyas* two. This list will no doubt be added to later on. I only wish in this paper to mention a very few of the red mites, chiefly to show the difference in the external structure of these beautiful creatures, to mention and figure all the known British red mites would take up too much space.

Water mites, as far as is known, generally deposit their eggs on the leaves and stems of water plants. Fig. 1, the under side of a leaf of *Anacharis* is intended to show how the ova of a beautiful red mite with blue legs—*Limnesia histronica*—(Hermann) were deposited. The eggs were not red, but deep orange-yellow. After a number of days, the time varying in different species, the larva (fig. 2), which is hexapod, is hatched out. During this stage many if not all larvæ become parasitic on some other form of pond life. Fig. 4 is a small red mite in the larval or parasitic stage, taken from the leg of a water-boatman

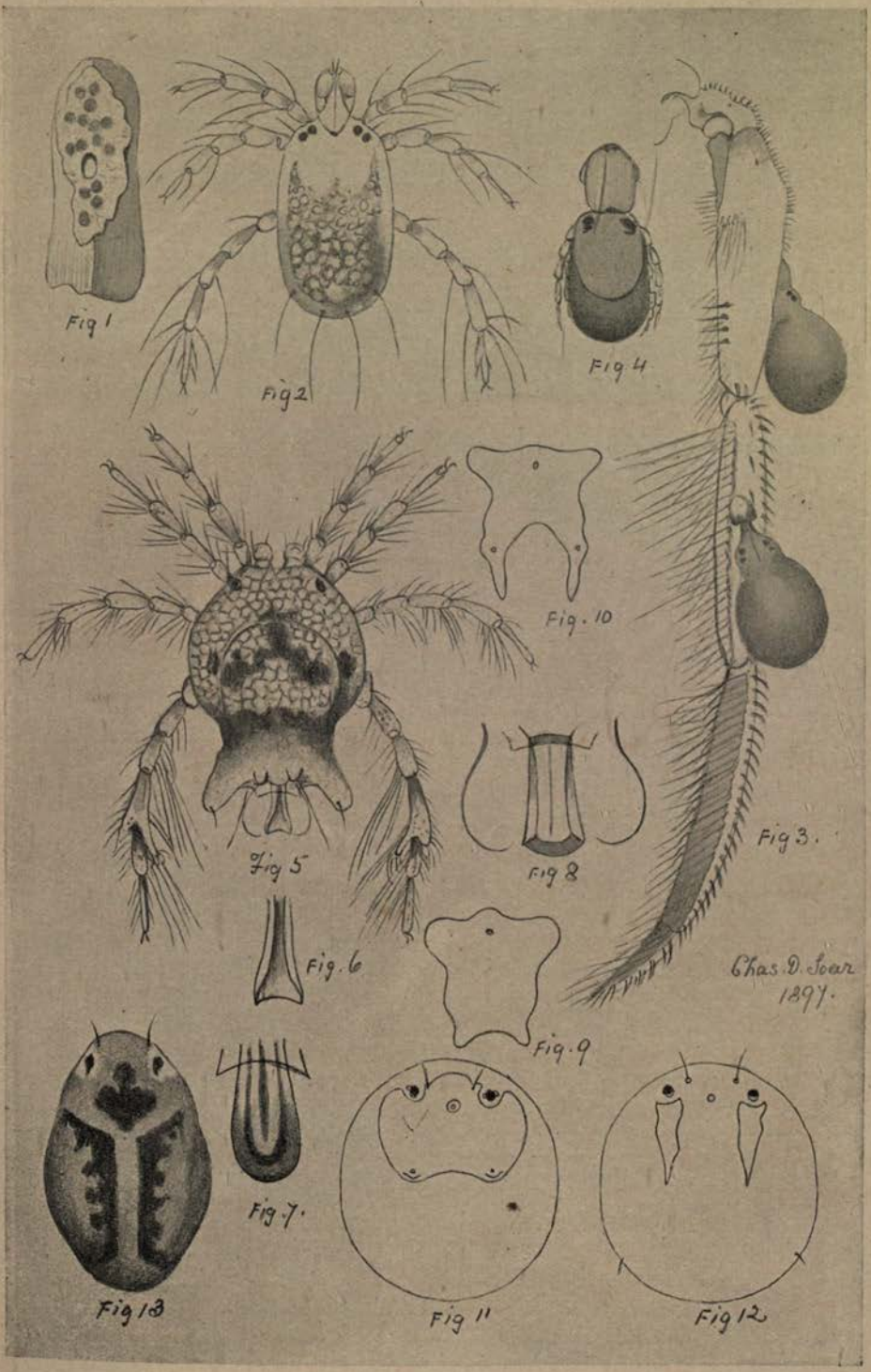


Fig 1
Fig 2
Fig 4
Fig 3.
Fig. 10
Fig 5
Fig 8
Fig. 6
Fig. 9
Chas. D. Soar
1897.
Fig 7.
Fig 13
Fig 11
Fig 12

Corixa Geoffroyi; it is very small, and had not taken up its abode very long, because the legs are still visible, when they have lived on their host for some time and have grown very considerably, the legs have either disappeared altogether or have shrivelled up into a very small compass, being of no further use to the little creature. Fig 3, which is the leg of a *Corixa Geoffroyi* with two parasitic water mites hanging on by their suctorial organs, will explain what I mean. These last mentioned are, I believe, the larval stage of *Limnesia histrionica*, quite a different species to fig. 4, which I believe to be one of the red *Arrenurus*. So little is known at present about the larval stages of water mites, that it is almost impossible to name the species correctly from the larvæ. After having spent some time in the state just mentioned they become free swimming, with eight legs, and are now very much like the adults, so much so, that you can now tell with tolerable certainty the species to which they belong.

All the members of the genus *Arrenurus* are hard-skinned mites, the males only have tails, the females being without these appendages. Fig. 5 is the male of *Arrenurus tricuspidator* (Müller), a very brilliant red mite. It can easily be recognised by the peculiar formation of its tail (see fig. 6, which I have drawn larger to make it more distinct). Fig. 7 is the tail of another red mite of the same genus *A. crassipetiolatus* (Koenike), figured in *Science Gossip*, January, 1897, and I think rather rare, as I have only seen two specimens, both of which were kindly sent to me by Dr. George, of Kirton-Lindsey. Fig. 8 is the tail of *Arrenurus emarginator* (Müller), a very large red mite. I believe we shall have several more red mites to place in this genus later, because I have several red females that I cannot name until the males are taken.

The genus *Hydrachna* contains soft-bodied mites, which can be recognised by the mouth organs projecting as far forward as the palpus. In this genus we have two red mites. Fig. 11 is *H. cruenta* (Müll), easily known by the patch on the dorsal surface behind the eyes. Fig. 12 is *H. globosa* (De Geer).

The genus *Hydrodroma* is also represented by two red mites, also distinguished for the patch on the dorsal surface. Fig. 9 is *H. rubra* (De Geer). Fig. 10 is *H. helvetica* (Haller).

The genus *Nesæa* has several red mites. I have only drawn one to show the difference in shape to those mentioned before. Fig. 13 is *Nesæa rufus* (Koch) a very bright red mite, with dark brown markings.

Of course, all fresh-water mites are not red, all colours being represented in these beautiful creatures more or less, but I think I have said enough to show that instead of anyone capturing the common red water mite it is much more likely that he has only captured a mite of a common colour.

PREPARING, CUTTING, STAINING, AND MOUNTING SECTIONS OF BOTANICAL TISSUES.

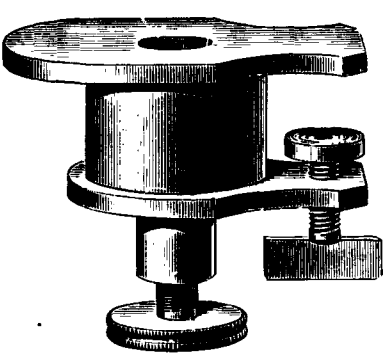
By Martin J. Cole.

THERE is no branch of Practical Microscopy more interesting than the study of the structure of vegetable tissues, a marvellous variety of which can always be readily obtained, and I now propose to show how easily such specimens can be prepared.

HARDENING AND FIXING.—Stems, roots and leaves should be gathered, cut into small pieces about half-an-inch long, and placed in a small bottle of methylated spirit; change the spirit every day until no colour comes away from the tissues. They may then be cut into sections or be kept for any length of time.

SECTION CUTTING.—Sections of soft stems and roots may be cut by hand with an ordinary razor. Hold the specimen between the thumb and forefinger of the left hand. Keep the finger straight, so that its upper surface may form a rest for the razor to slide on. Take the razor, hold it firmly in the hand, and keep the handle in a line with the blade, and draw it through the tissue from heel to tip towards yourself. While cutting, keep the razor well wetted with methylated spirit, and as the sections are cut place them in a saucer of clean water. When specimens are too small to be held by the hand, they may be embedded in carrot. Take a piece of carrot, about an inch long, cut it in half longitudinally, place the tissue between the two halves, and tie together with some twine, then proceed to cut the sections as before. Hand cutting is all very well for rough work, but it is very difficult to get good even sections, and I would suggest that all students should have a good microtome of some kind. The best I know of for all-round work is that made by Messrs. W. Watson & Sons, 313, High Holborn, who supply it complete with punches and knife for £1 14s. 6d.

Screw the microtome firmly to a table, and with the large brass tube punch out a cylinder of carrot to fit into the well of microtome. Cut this in half longitudinally, and with one of the smaller punches scoop out enough space in one half of the carrot to take the specimen; then place the other half of carrot in position, and make sure that the specimen is held firmly between them, but, of course, it must not be crushed. Now put the cylinder of carrot and specimen into the well of the microtome and cut the sections. While cutting, keep the knife and the surface of the microtome well wetted with methylated spirit, and as the sections are cut place them in a saucer of water.



In order to investigate the structure of a plant stem correctly, it is necessary to have a longitudinal section as well as a transverse. To obtain this, cut off

about $\frac{1}{8}$ inch of the stem transversely, and place it horizontally in the groove of the carrot, with its flat ends against the walls of the cavity, then place in microtome and cut sections.

When the specimen has an irregular surface it must be imbedded in paraffin. Take some paraffin wax and melt over a water bath. Place the specimen in the well of the microtome in the desired position, pour in enough paraffin to cover it and allow to cool, then cut sections as before.

BLEACHING.—Vegetable sections usually require bleaching before they can be properly stained. Chlorinated soda is used for this purpose.

Take of dry chloride of lime, two ounces; of common washing soda, four ounces: and distilled water, two pints. Mix the lime in one pint of water and dissolve the soda in the other. Mix the two solutions together, shake well, and let the mixture stand for twenty-four hours. Pour off the clear fluid, filter through paper, and keep in a stoppered bottle in a dark place, or cover the bottle with black paper.

Place the sections to be bleached in a bottle of distilled water, and soak until all trace of spirit is removed, pour off the water and add bleaching fluid, cork up well and let it stand for from one to twelve hours, according to the nature of the specimen. As a rule, the tissue should be quite white, but some parts of sections will never lose all colour, for instance, Rhizome of *Pteris Aquilina;* in this case, as soon as the hard black sclirenchyma turns yellow, stop the bleaching. Pour off bleaching fluid, add water, and keep on changing the water until all trace of smell of chlorine is removed, then give a final wash in distilled water, and proceed with the staining, or the sections may be bottled up in methylated spirit until required.

STAINING.—Sections of ovaries and young stems that do not contain much woody tissue, should be stained in Hœmatoxylin.

Hœmatoxylin	30 grains.
Absolute alcohol	$3\frac{1}{2}$ ounces.
Distilled water	$3\frac{1}{2}$,,
Glycerine	3 ,,
Ammonia alum	30 grains
Glacial acetic acid	3 drams.

Dissolve the hœmatoxylin in the alcohol, and the alum in the water; then add, to the latter, the acetic acid. Mix the two solutions together, and let the mixture stand for at least a month before use. This stain is rather troublesome to make, it is better to buy a bottle ready made, most of the leading opticians supply it.

1. Add about 30 drops of the solution of hœmatoxylin to an ounce of distilled water, and stain the section for fifteen to twenty minutes.
2. Wash well in distilled water.
3. Soak for a few minutes in ordinary tap water until the colour becomes blue.
4. Place in strong methylated spirit and dehydrate for at least ten minutes.
5. Place in clove oil to clear for about five or ten minutes.
6. Mount in Canada balsam.

Most stems, roots and leaves can be double stained with the following staining solutions:

BORAX CARMINE.

Pure carmine	1 dram.
Liq. ammonia	2 drams.

Dissolve the ammonia and add twelve ounces of saturated solution of borax in distilled water; filter and keep in a stoppered bottle.

1. Place the section in a little of the above stain in a watch glass for about five minutes.
2. Wash well in methylated spirit.
3. Take of hydrochloric acid, 1 part; and of methylated spirit, 20 parts. Mix together and soak the section until it becomes of a bright scarlet colour; if over stained, until the excess of stain is removed.
4. Wash well in methylated spirit.
5. Make up an alcoholic solution of Grüblers' acid aniline green in methylated spirit, about two grains to an ounce of spirit, filter and immerse the section for ten to fifteen minutes.
6. Wash well in methylated spirit; if over stained with the green, soak until the excess of colour is removed. The different parts of the specimen should be distinctly visible to the naked eye—woody tissues, green; parenchyma, red.
7. Dehydrate in methylated spirit.
8. Clear in clove oil.
9. Mount in Canada balsam.

The acid aniline green can be obtained from Mr. C. Baker, 244, High Holborn.

MOUNTING IN CANADA BALSAM.—Take three ounces of dried Canada balsam and dissolve in three fluid ounces of best benzole, filter and keep in a stoppered bottle.

Clean a glass slide, take up a little balsam with a glass rod and place a few drops on the centre of the slide, take the section out of the clove oil on a lifter and place it in the balsam on the slide. Clean a cover glass, and with the aid of a pair of fine forceps, carefully put the edge of the cover into the balsam, ease it down so that no air bubbles may be included in the mount. When the balsam has completely covered the under surface of the cover-glass, press gently on its upper surface with the point of the forceps, this will squeeze out any excess of balsam, and set the section quite flat. Now put away for about twenty-four hours to dry.

When the balsam has dried, take a soft camel's-hair brush with rather long hairs, and with a little methylated chloroform carefully wash away the exuded balsam from around the edge of the cover-glass, drain off the chloroform and allow the slide to dry by exposure to air only. When dry, place the slide in a turntable and run on a ring of some good shellac cement. I have found an enamel used for bicycles answer very well. It is known as Tringham's Enamel, and it can be obtained at most cycle depôts. As sold, it is rather too thin for microscopical work, but this difficulty is easily overcome by allowing it to evaporate for a few days. Having applied a ring of cement, it must be allowed to dry for about twelve hours, then take a piece of soft rag and some turpentine, and carefully wash away any trace of balsam and chloroform, dry with a clean cloth and apply a second coat of enamel.

THE MICROSCOPE IN 1897.
REVIEW OF NEW APPARATUS.

Dr. Henri Van Heurck, Hon. F.R.M.S., etc.

Professor of Botany and Director of the Botanical Gardens at Antwerp; Hon. F. New York M.S., Hon. F. Illinois M.S., etc.

WE propose in this article to review the progress made in the construction of microscopical instruments during the last few years, reviewing the improvements made in instruments and apparatus since the English edition of our "Traité du Microscope" appeared in 1893. Unfortunately there is not one important invention to chronicle during this period, beyond the introduction of a few new models, and the improvement of details in apparatus already existing.

To establish a little order in our review, we will examine successively the instruments produced by the best-known makers in Europe, the short time allowed to us for this article not permitting us to procure the necessary particulars from America. We hope, however, to return to the subject in next year's annual.

R. & J. Beck, London.— These makers have lately produced a few new models, resembling the continental micro-

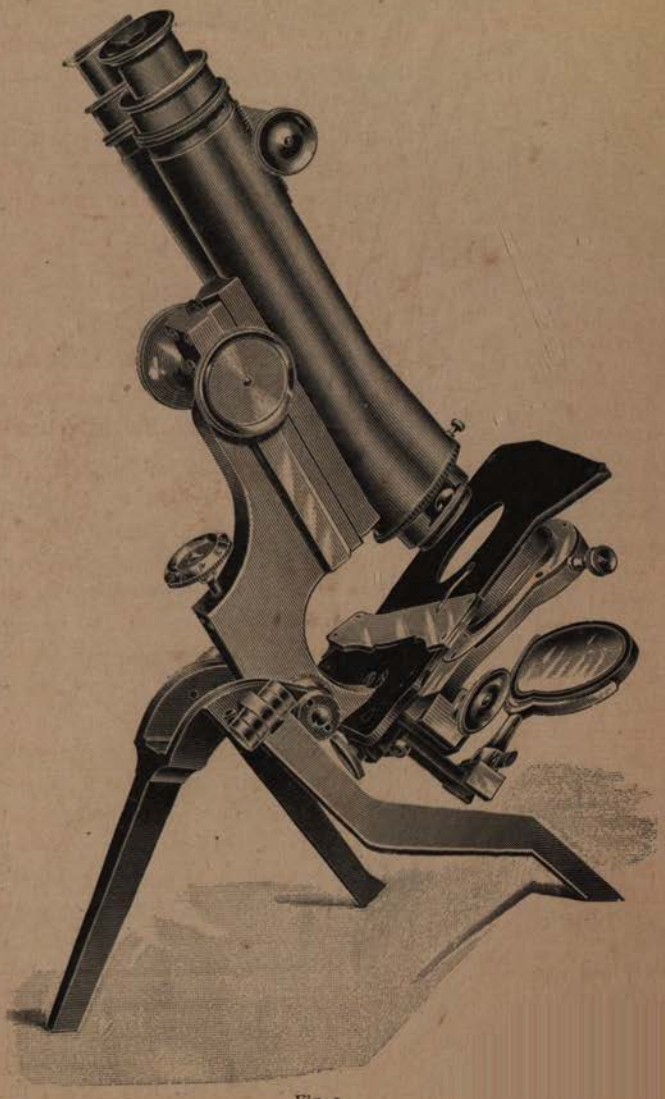


Fig. 1.

scopes, which they call "Continental Model," the largest of which (No. 51) is very convenient for all ordinary research.

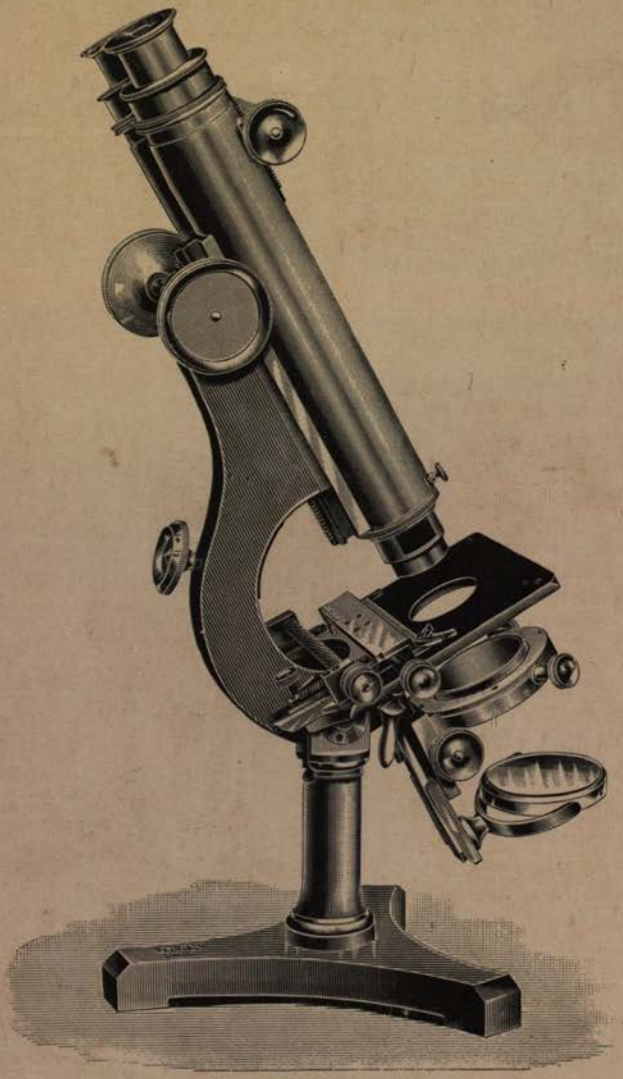


Fig. 2.

Among their new stands of the "English type" we may mention the "New form portable binocular national microscope," which is intended for travelling purposes. The feet fold up, the stage and substage can be removed, and consequently the whole occupies very little space, and can be packed in a small box measuring $13 \times 7\frac{1}{2} \times 3\frac{1}{2}$ ins. (fig. 1). Another fresh type is the "New form binocular national microscope," having a large square stage and a removable substage (fig. 2.)

For observation, and especially for photo-micrography, Messrs. Beck have lately constructed an achromatic condenser (fig. 3) having a numerical aperture of 1·0. This instrument, which is as nearly perfect as it is possible to make it, is furnished with an Iris diaphragm, a rotating disc containing stops for dark-ground illumination, and a second one carrying a series of blue glasses for modifying the illumination.

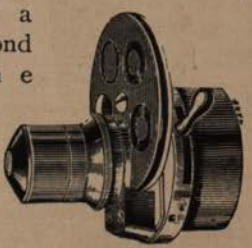


Fig. 3.

Finally we will call attention to two small instruments:

1st. A photographic shutter, which is placed immediately above the lens (fig. 4), and which is formed of a tube in which slides a plate with an eccentric opening, permitting the admission of the light at any given moment. The part of the

apparatus in which this plate slides turns freely on its own axis, so that the button by which the plate is manipulated can be placed in the most convenient position for use.

Fig. 4.

2nd. The New Medical Centrifuge (fig. 5), an apparatus serving to precipitate rapidly blood, urine, pus, milk, etc. It makes five thousand revolutions per minute, and its principal parts are made of aluminium. The effect of this rapid revolution is that the corpuscles suspended in the liquids are rapidly driven to the bottom of the tubes and deposits can be almost immediately obtained, which would ordinarily only form at the end of one or two days. For the study of micro-organisms, and especially for diatoms, this instrument is very useful.

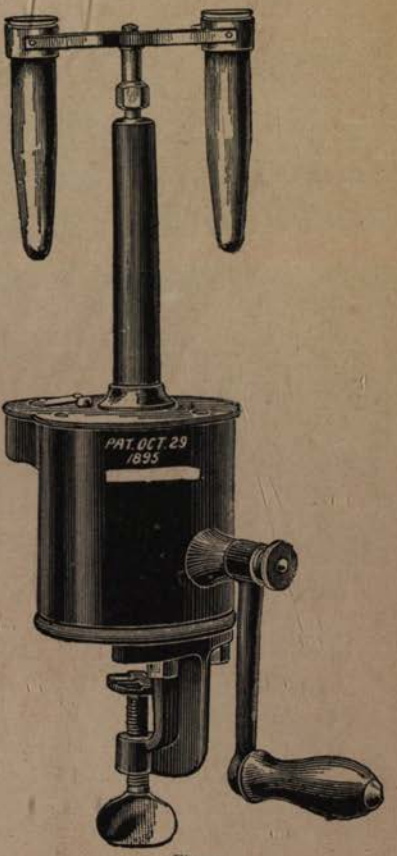


Fig. 5.

Henry Crouch, London.—Mr. Henry Crouch has of late been successfully occupied in improving his stand and his lenses, of which latter he has succeeded in increasing the numerical aperture and considerably correcting the aberrations, while at the same time producing them at very low prices.

Fig. 6.

R. Fuess, Stieglitz, near Berlin, has introduced a small camera (fig. 6) which can be adapted to any microscope. This apparatus, which is sufficiently explained by the accompanying figure, is made entirely of aluminium, and takes plates $4\frac{1}{4} \times 3\frac{1}{4}$ ins. It is fixed in a few seconds, and is always ready for use, whatever the position or place of the microscope. It is very useful, for if during an observation one notices any objects of which it is desirable to keep a record, it can at once be used. The cost of this apparatus is very moderate.

F. Koristka, Milan, has also been actively employed in the improvement of his existing apparatus. The stage of the principal instruments has been coated with ebonite, and some small models have been added to the series already existing.

A stand, specially designed for mineralogical investigation, has been added to the ordinary instruments of research. To the collection of lenses has been added a $\frac{1}{15}$th in. semi-apochromatic. This lens costs 200 frs. (£8), including two compensating oculars, and serves for all work where photo-micrography is not required.

The series of photo-micrographic instruments has been increased by the addition of a simplified vertical camera, which is supplied at 75 frs. (£3) and takes plates 9 × 12 ccm.

Leitz, Wetzlar, has introduced several modifications into his stands, and two among them, Nos. 12 and 11b, have been furnished with a tripod, after the English style. Two new instruments have been added. One is a school microscope, which can be easily passed round from one person to another. The other, the "Schlitten-Mikroskop" (Sliding microscope), is an instrument intended for the examination of large histological sections, also for the study of bacteriological culture plates. The plate is about 20 mm. long and 16 mm. wide, and the tube of the microscope and the slide are attached to each other by a groove, and can be quickly removed in favour of magnifying glass carriers.

In the large stands, the arrangement of the apparatus for lighting has been altered. The Abbe condenser can be lifted from the optical axis by means of a hinge, and the Iris diaphragm immediately put in its place.

Among the new lenses constructed by M. Leitz, we must notice a $\frac{1}{10}$th water immersion, and one of about 80 mm. focus, furnished with an Iris diaphragm, intended only for projection purposes. In addition, there are three special photographic lenses of 64 mm., 42 mm. and 24 mm. focus respectively.

A small instrument, which we have in daily use and which we can particularly recommend, is the ocular camera lucida, which is formed by the permanent union of an eye-piece and a prism; by reason of this combination made once for all, under the best conditions the manipulation of the instrument is an easy matter, and the wearisome adjusting so general with an independent camera lucida is entirely avoided.

Fig. 7.

Herr Leitz makes two models of this useful accessory, the one intended for the vertical microscope (fig. 7), the other for the sloping microscope (fig. 8).

Fig. 8.

Nachet et Fils, Paris.—The old and well-known firm of Nachet, of Paris, has just increased its importance by becoming incorporated with the old firm of Hartnack-Prazmowski (Bezu, Hausser & Cie., sucrs.). They have therefore centralized in their workshops the highest grade of French microscopy.

This firm has during late years noticeably improved the construction of its

lenses by the introduction of Jena glasses. Its lenses for immersion, among others the $\frac{1}{12}$th and $\frac{1}{18}$th, are very beautiful and rival the apochromatics for histological work. Some new stands have also been made during the last few years, of these we will mention :

The microscope with a wide range of vision for examining large surfaces, an instrument which has lately been imitated by several other makers. The

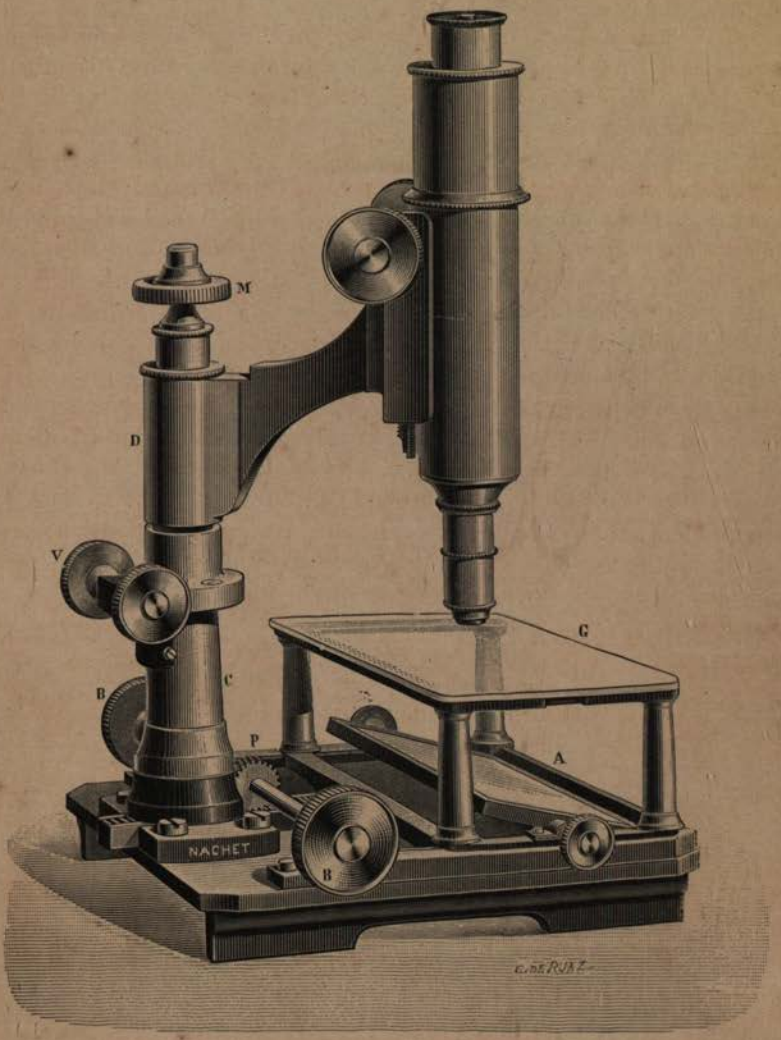


Fig. 9.

mechanical arrangements represented in fig. 9 show the varied applications of this microscope The stage which is of glass and of large dimensions (10 × 14 cm.) is carried by a frame G, which can by means of a rack, BB', be moved laterally ; the support of the body D, carrying the optical portion, turns horizontally on an axis, by means of a tangent screw V, and gives ample

movement up to 14 cm. The systematic examination of the preparation then takes place : 1st, by the longitudinal displacement of the stage, by means of the rack BB, and 2nd, by the transverse displacement of the optical combination

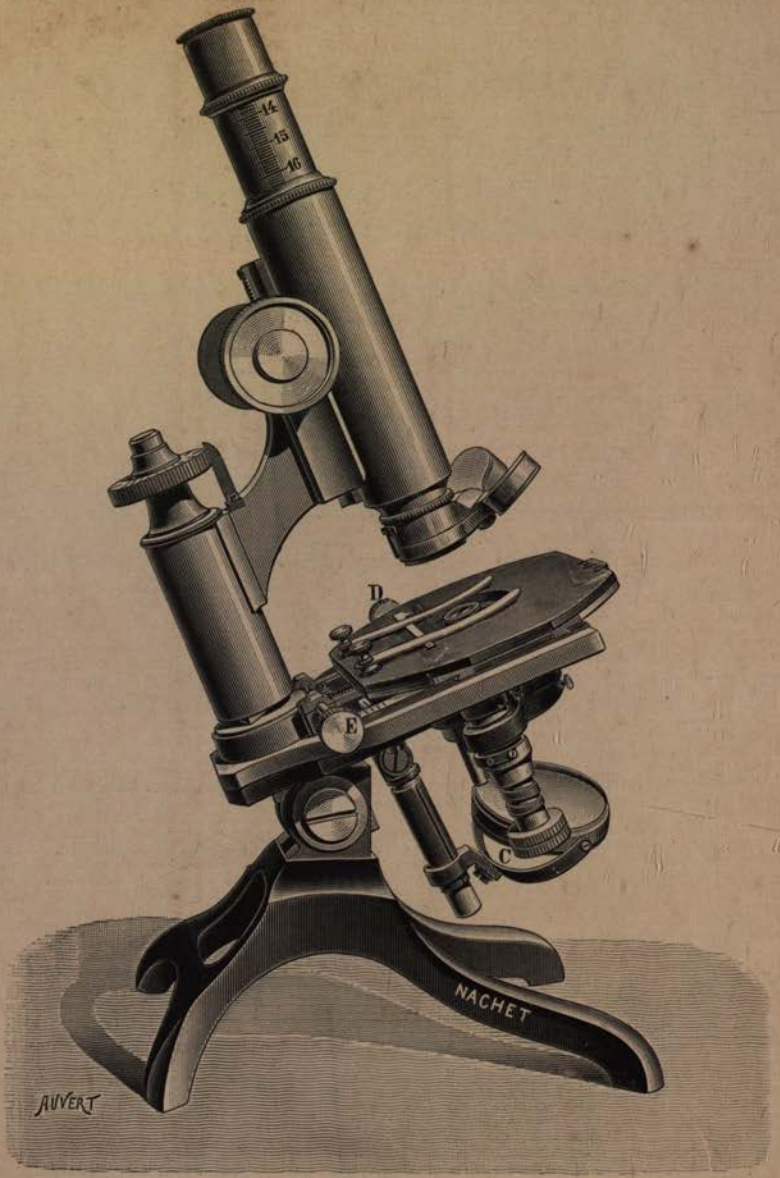


Fig. 10.

circulating on the preparation, which offers the advantage of suppressing the transverse movement of the stage.

The illumination is obtained by means of a large flat mirror, which will light

the surface of the largest preparations, or of a concave mirror for observations with strong magnifying powers; in this case, the glass stage can be replaced by one of ebonite. The whole of the instrument is thoroughly well made.

The micrometric screw M, and the rack for coarse adjustment are constructed

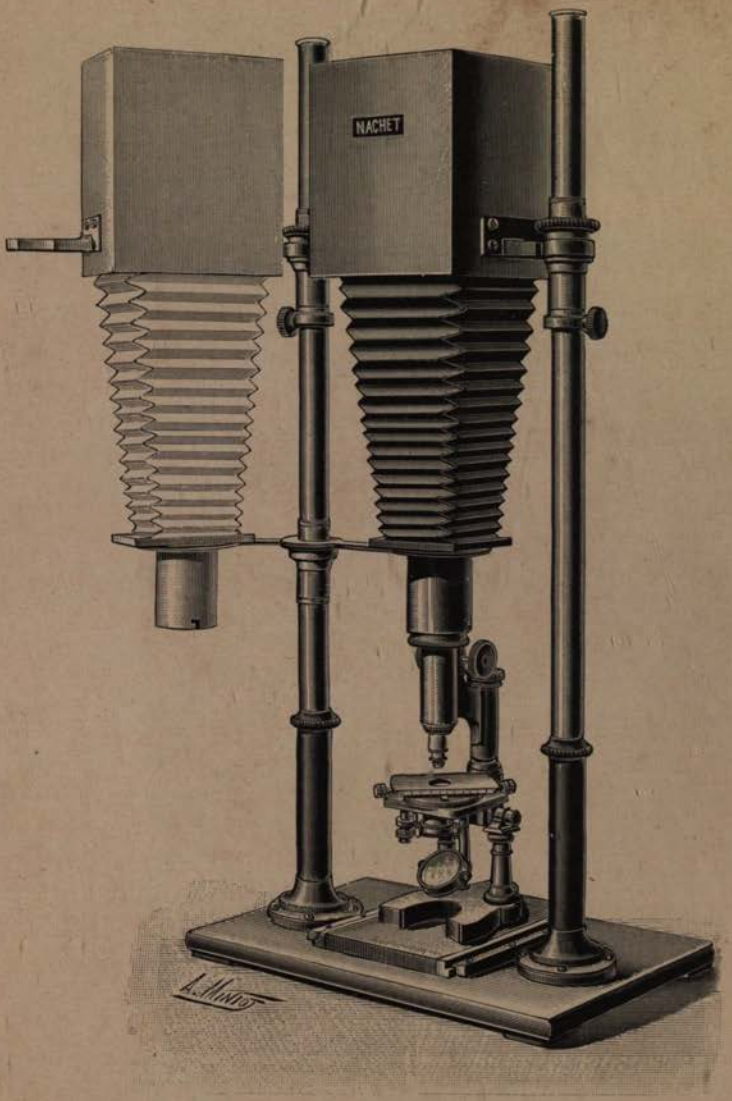


Fig. 11.

with the greatest perfection and permit the use of lenses of high power. The body, of a large diameter, carries a *special eyepiece of wide angle* which, combined with the lens No. 1, permits a field of 50 mm. diameter to be embraced when magnified five times; with No. 1a (special) an extent of 18 mm. magnified fifteen times, and with No. 2 an extent of 9 mm. magnified twenty-four times.

2nd. The large model, No. 4 (fig. 10), is very solid, and to be recommended on account of its construction, finish and elegance. It possesses a mechanical stage, which allows of considerable displacement in every direction, an Abbe illuminating apparatus with Iris diaphragm, which can be quickly made eccentric, and a cylinder Iris diaphragm in a cupola.

Among the photo-micrographic instruments, a new model called the "Vertical Camera, large model," has been added to the previous series. This apparatus is composed of a pedestal carrying two metal pillars between which slides a 9 × 12 camera, provided with bellows which have at the lower extremity a connection by means of which the camera is joined to the microscope. The union is composed of two tubes sliding one inside the other, but completely independent. The lower tube screws on to the body of the microscope, of which the draw-tube has been previously unscrewed; this is the arrangement for photographing with the lens alone. When it is desired to photograph with the projection eyepiece, the bellows and the upper tube are removed, and into the lower tube another one with special eyepiece is screwed.

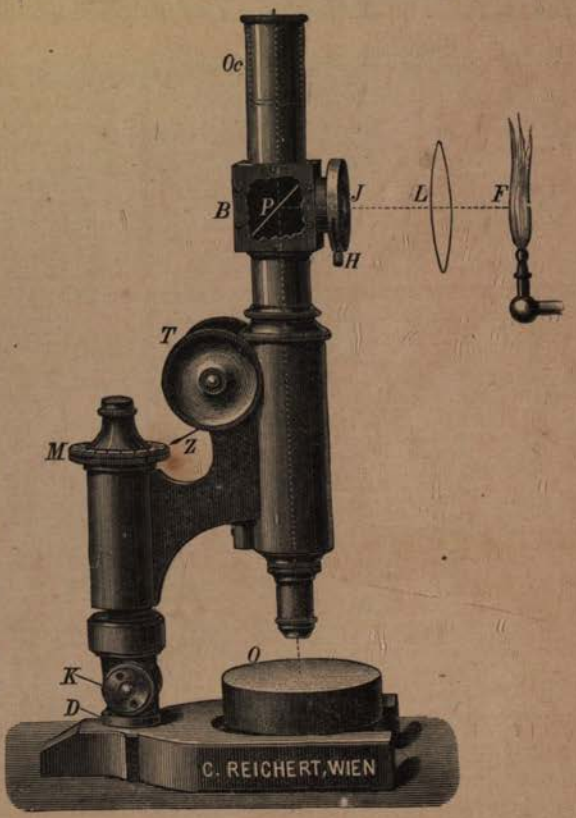


Fig. 12.

By means of the bellows with which the camera is furnished, the ground glass can be moved nearer or further away to make the images larger or smaller.

Further it is only necessary to raise the bellows in order to separate them from the microscope and to turn the camera round one of the pillars, as shown in fig. 11, so as to be able, without any inconvenience and without altering the lighting, to use the microscope and to arrange the preparation.

Powell & Lealand, London.—This firm has not, during the last few years, introduced any changes into its constructions. Its stands and lenses are, however, all of the best quality, and the firm can scarcely fulfil all the orders which it receives.

Carl Reichert, Vienna (Austria), has not introduced any noticeable alterations into his ordinary models, but Nos. III. and VII. have been provided

with a tripod after the English style. A new and interesting model (fig. 12), No. VIII. (15b), is intended for the examination of opaque objects, and especially of fractures and corrosion in metals. The rays emanating from a flame F, are reflected on the object by means of a transparent glass P.

Herr Reichert has lately given his special attention to the improvement of instruments for photo-micrography, and we have received photographs of a large and beautiful apparatus which is now in course of construction. The base and the slides are made entirely of cast iron and the whole is perfectly rigid.

The series of lenses is still the same as in 1893, but the maker has considerably improved the correction of the aberrations, so that the present lenses, that is to say, the achromatic ones are as perfect as possible.

Fig. 13.

Fig. 14.

Ross Ltd., London.—Messrs. Ross Ltd. still supply their old well-known models, the "Wenham's Radial Arm," and the "Ross-Zentmayer," but along with these they now make a series of stands which are in reality continental microscopes. Such are the "New Inclined Eclipse" and the "Pillar-Foot Eclipse" (fig. 13), which are no other than the old large Hartnack microscope, with an Iris diaphragm (fig. 14).

The "Anglo-Continental" combines the precision of English instruments and the simplicity of the slow movement usually applied to continental instruments (fig. 15). This apparatus can be procured either with a circular foot, as shown in the figure, or with a tripod.

W. & H. Seibert, Wetzlar.—Besides its large model, which it still makes, but to which it has added a removable mechanical stage (fig. 16), this firm now manufactures a series of extra strong pattern, the type generally adopted in Germany.

Special mention should be made of this firm's condenser, large model. It is the one instrument of this class which permits of the most rapid change from lighting by a condenser to lighting by a simple mirror.

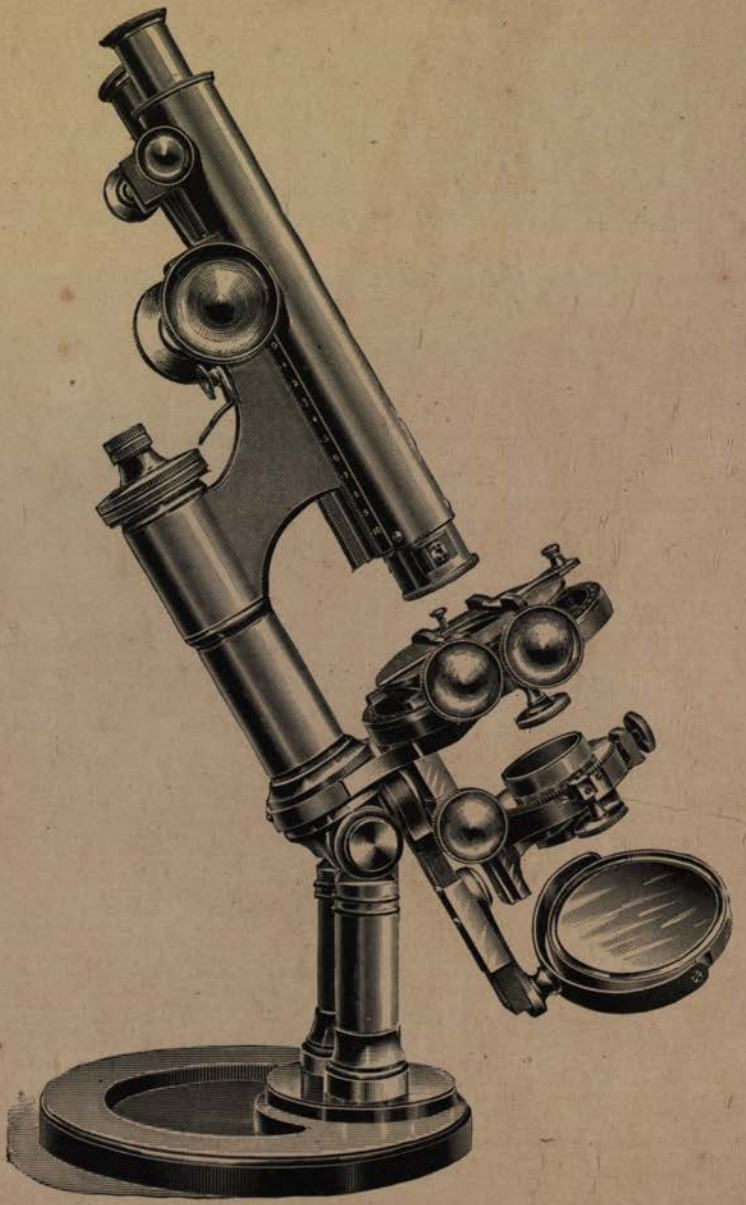


Fig. 15.

To effect this, it is only necessary to withdraw the condenser (fig. 17), which is adapted by sliding below the stage. From this moment, an Iris diaphragm

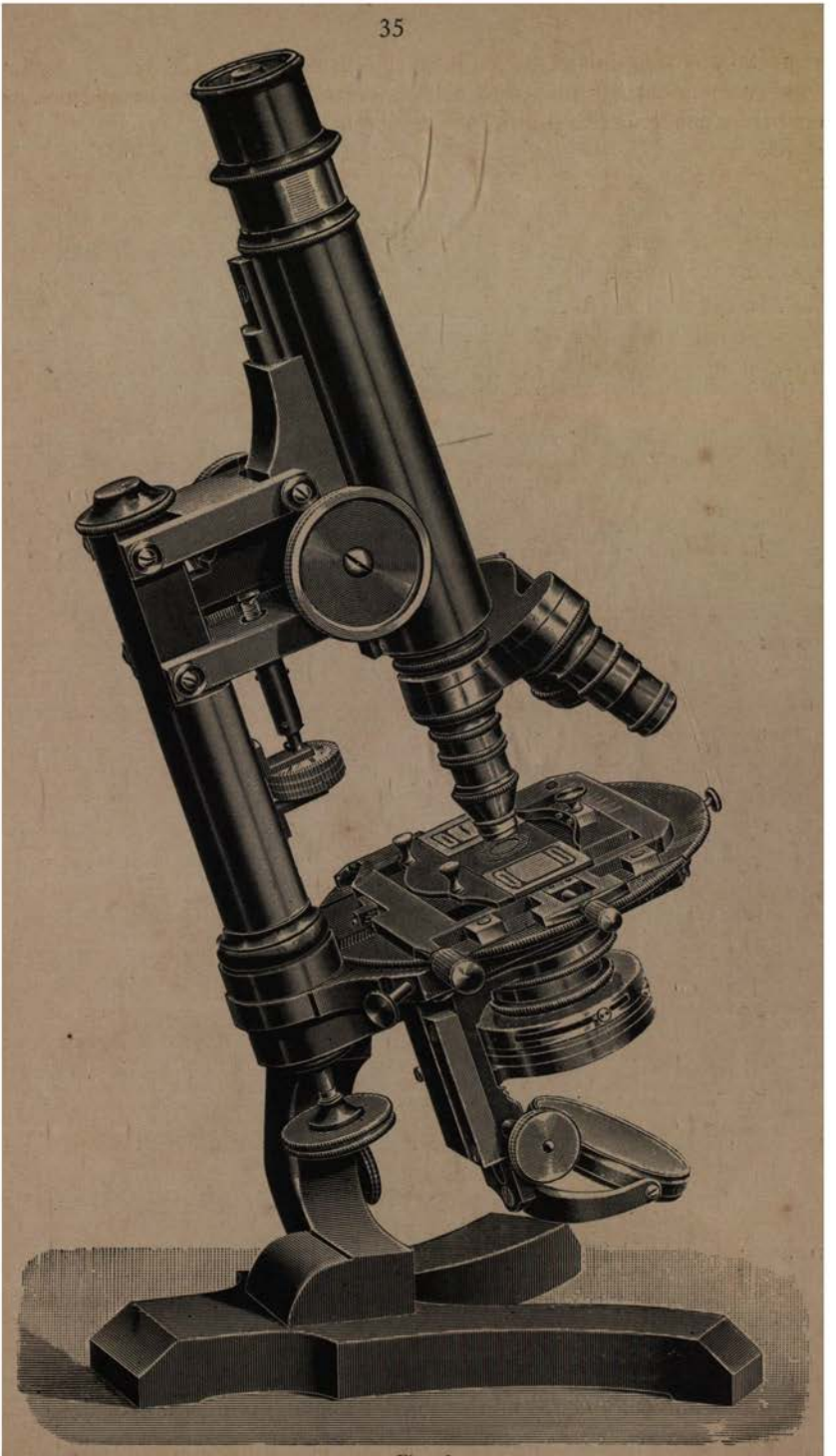


Fig. 16.

comes into play supplying the place of a diaphragm of the old pattern.

These makers have also lately improved their lenses, which have, however, long been known as excellent, and which are sold at reasonable prices. We will mention especially the apochromatic of 1·5 focus and of N.A. 1·40, which we frequently used during the last few years and which only costs about £20.

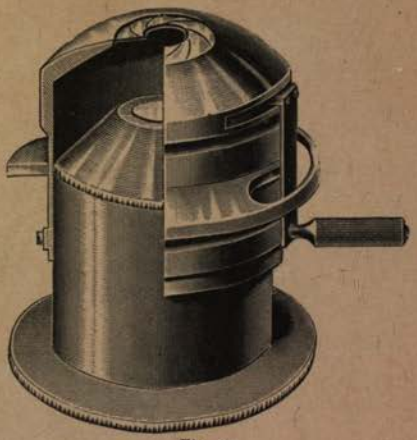


Fig. 17.

WATSON & SONS, LONDON, who have acquired such a high reputation for their stands, have again lately introduced some new models, among which we will mention:

The "Grand Model Van Heurck Microscope" (fig. 18), which was shown at the exhibition which has just been held at Brussels.

This model is characterized by its mechanical stage, which revolves completely on its own axis; by the perfect stability afforded by the spread of its tripod, by its large mirrors of which the plane one is optically worked, thus giving only a single reflection of the flame. The optical centre of the instrument, when it is placed horizontally, is exactly 10 ins.—the distance of normal vision—above the table.

The "Edinburgh Students' Tripod" is also a new model. It is a simplified Van Heurck microscope, for the use of observers who do not require the highest precision and who can only give a limited sum for an instrument (fig. 19).

A form of the Van Heurck microscope, intended for mineralogy is also in course of construction.

Fig. 20.

In the series of condensers, we must specially notice their "Parachromatic Condenser," N.A. 1·0, which is intended for the most delicate researches. Fig. 20 suffices to show the details of its construction.

A series of objectives bearing the name of "New Parachromatic Lenses," and ranging from 4 inches to $\frac{1}{10}$th of an an inch (all dry objectives), has lately been brought out. These glasses are as achromatic as possible, and resemble in correction the apochromatic objectives.

In the domain of photo-micrography, Messrs. Watson & Sons have, during late years, constructed a "Vertical Camera for Instantaneous Photo-micrography" made according to particulars supplied by Mr. Andrew Pringle. In this apparatus, which resembles the "Van Heurck Camera," a pneumatic bulb placed outside the camera works the shutter inside, giving time or instantaneous exposure as desired. The image can also be seen by means of a mirror, which

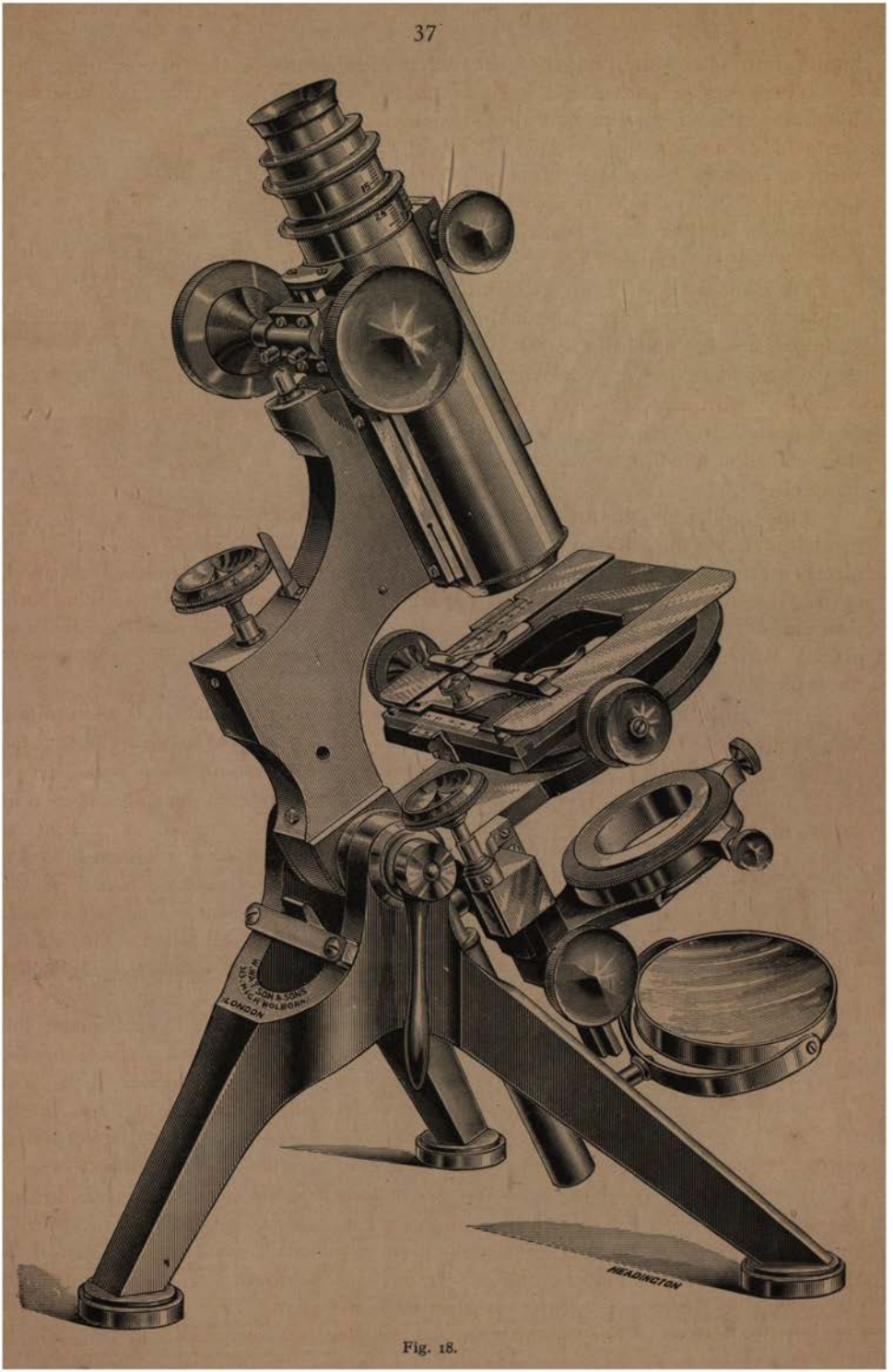


Fig. 18.

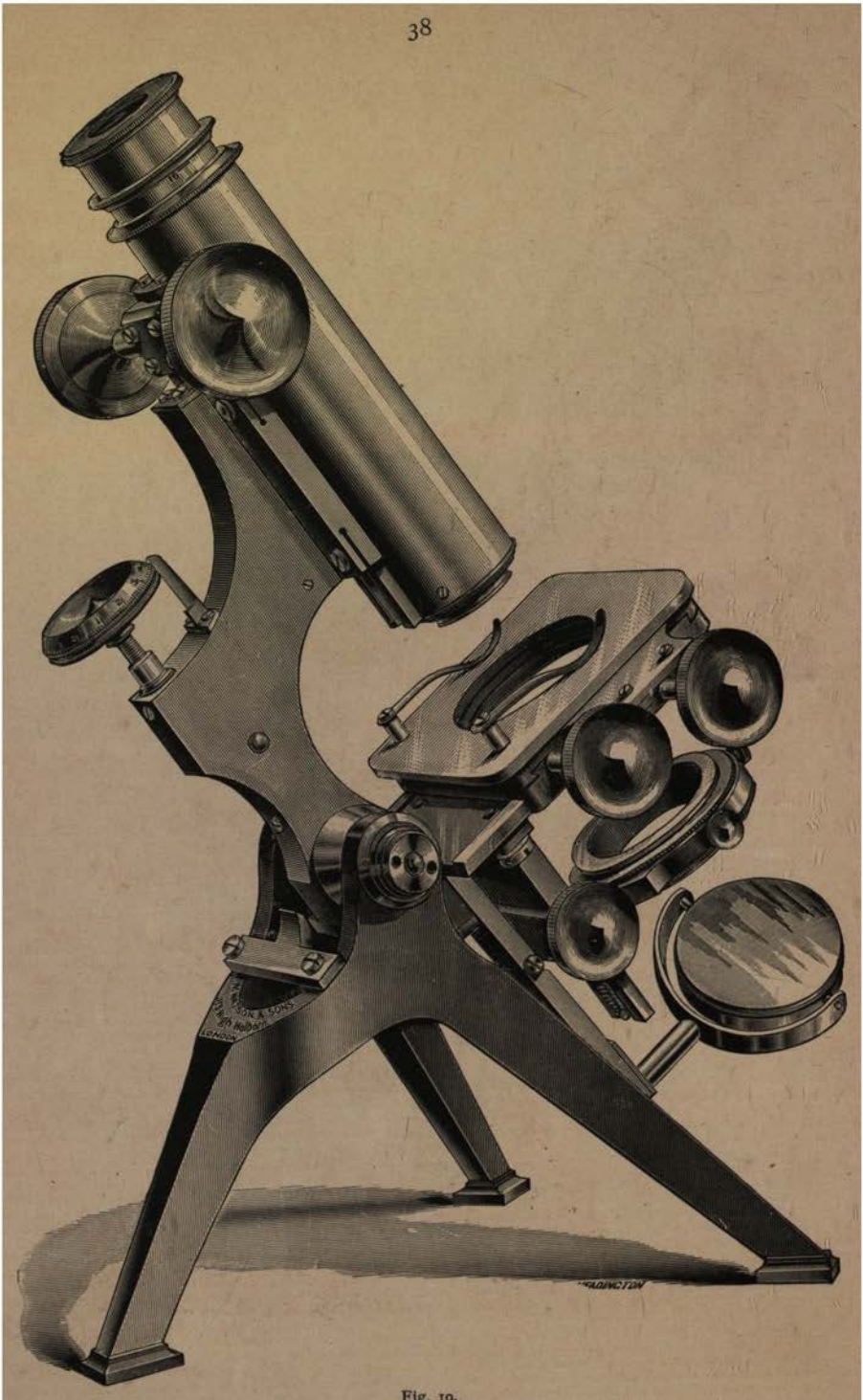


Fig. 19.

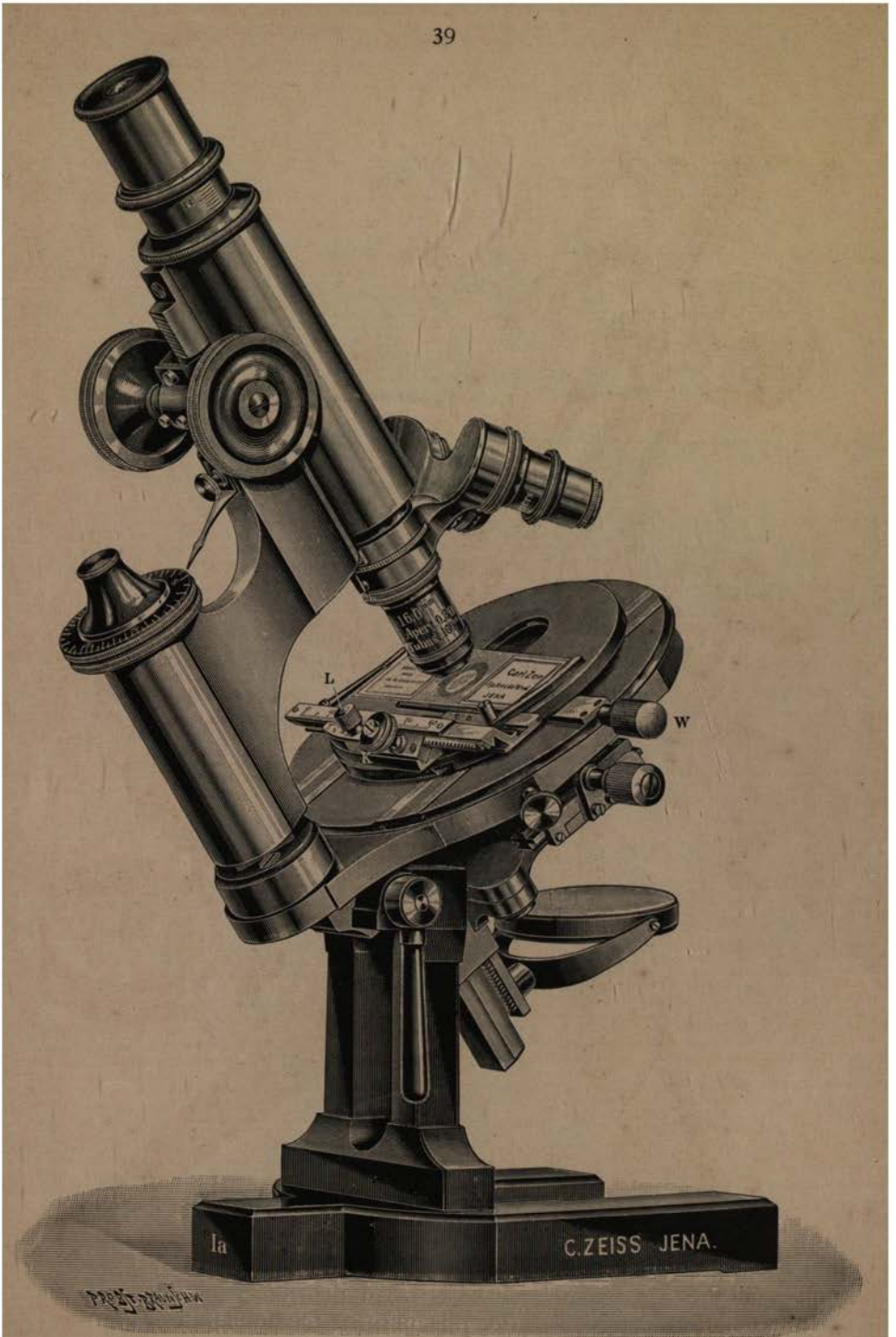


Fig. 21.

reflects it upon a disc of ground glass fitted in a tube at the side of the camera, thus the shutter can be opened exactly when the object is in the position and place desired by the observer.

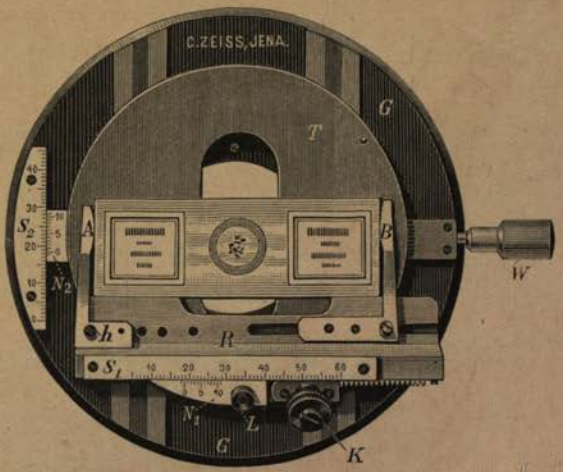


Fig. 22.

We hope to be able, in next year's Annual, to give a more detailed explanation of this instrument, together with an illustration.

The firm of Carl Zeiss, of Jena, which continues to hold the first place in contemporary micrography, has lately produced a series of new instruments,

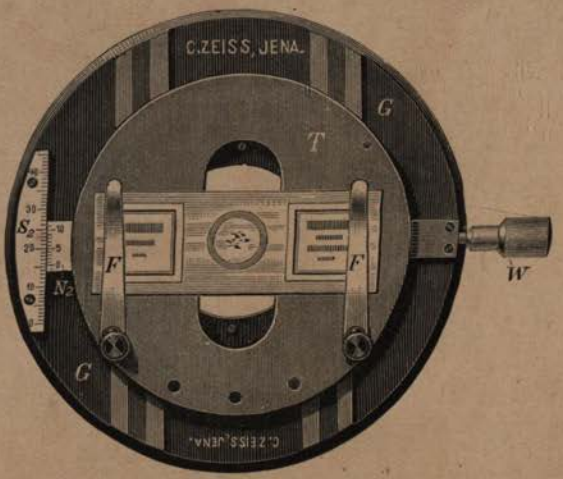


Fig. 23.

and has introduced considerable modifications into its lenses. The stand Ia (fig. 21) is made after the ordinary pattern of the firm, but is characterized by a new mechanical stage which is so constructed that it can be quickly fixed or removed from the microscope. For this purpose the frame R (fig. 22), which gives the transverse movement by means of the milled head K, lifts off, after

unscrewing the button L. The stage then assumes the appearance shown in the figure. There only remains the longitudinal movement, which is given by the

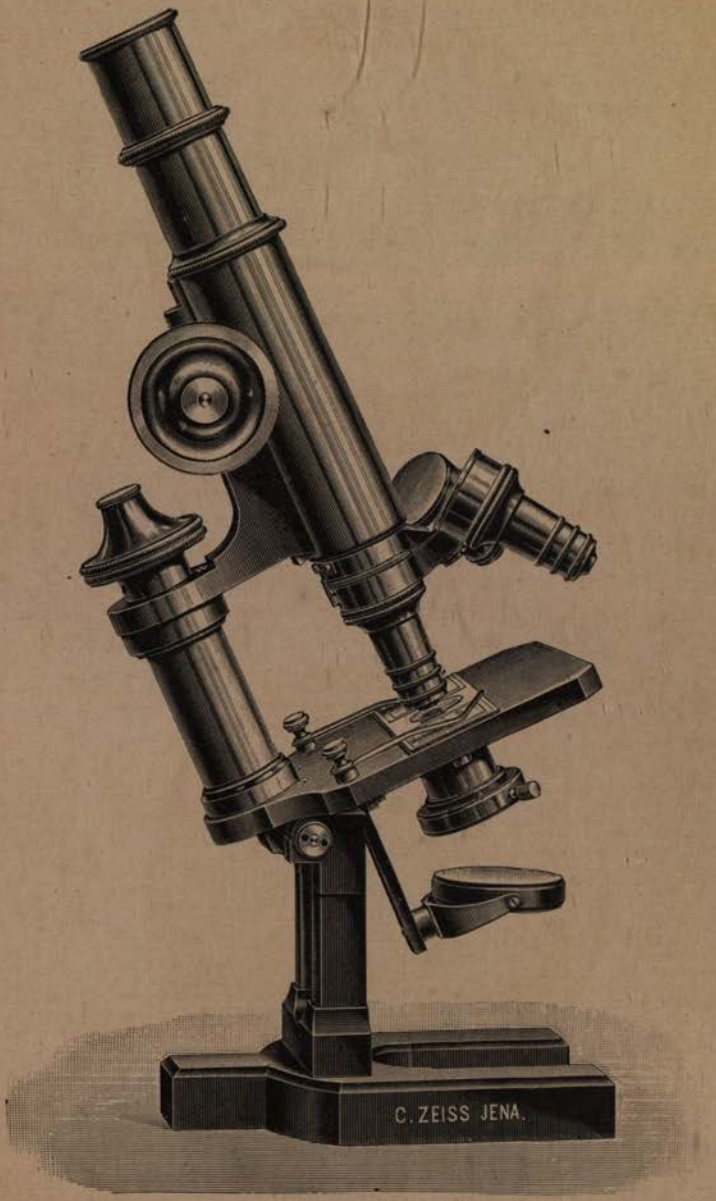


Fig. 24.

milled head W. Two supports F which are fitted into holes, arranged for this purpose, allow the preparation to be gripped (fig. 23).

Another stand, called "Stativ VI^{A}" (fig. 24), is derived from the "Oberhauser-Hartnack" model, and is intended to meet the needs of those with shallow purses. It has, however, been so constructed that it suffices for very delicate researches. Its movements are very exact, but its condenser, of which we give a separate figure (fig. 25), only permits of axial lighting.

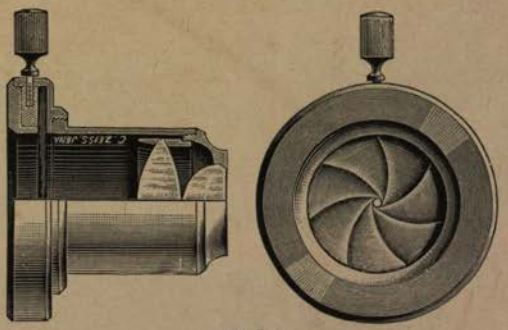


Fig. 25.

The condenser, which slides into a tube adjusted under the stage, can be removed and replaced by an Iris cylinder diaphragm (fig. 26).

This microscope is also suitable for travelling purposes, and is then supplied in a mahogany box, 30 × 30 × 17 cm. Packed in this, the instrument is guaranteed against all shocks when in transit. It is accompanied by three lenses and a suitable revolver nosepiece, a spirit lamp, three flasks in cases, object carriers and object-covers, also a chamois leather.

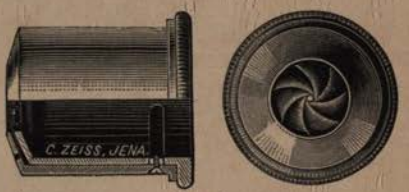
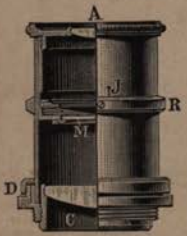


Fig. 26.



Among the new accessories, we notice an eyepiece of wide range with an Iris diaphragm, for the superficial examination of preparations and for drawing. This instrument gives a surface field more than double that of ordinary eyepieces, and is made either like Huygens's eyepiece No. 2, or like the No. 4 compensating eyepiece. The upper glass is movable, so that the micrometer, which can be arranged at will on the Iris, can be focussed. As this instrument cannot be slipped in the ordinary sliding tube, MM. Zeiss supply it with a thread (fig. 27) which screws into the wider portion of the tube, after having unscrewed the narrow upper eyepiece fitting.

Fig. 27.

A new stand for a magnifying glass (fig. 28) has the advantage of allowing, by means of a special joint, the lens to be moved about over the whole surface of the object, equally in any direction (fig. 28).

In the domain of photo-micrography, we must notice specially the new camera which can be used horizontally or vertically, and which answers all ordinary purposes, although the price is relatively very low (fig. 29).

As for the Zeiss lenses, which are certainly the best of this time, we will say little about them, for we have already had in hand for the last two years, a somewhat long work on the evolution of apochromatic objectives. In this work,

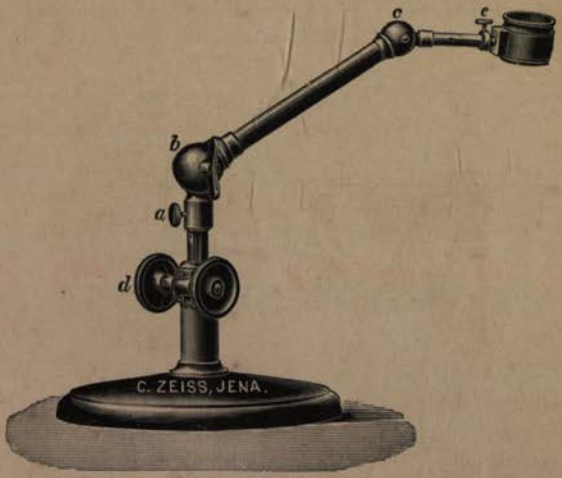


Fig. 28.

which we hope to publish very shortly, we shall examine every one of these lenses from every point of view. We will merely say that now, by reason of

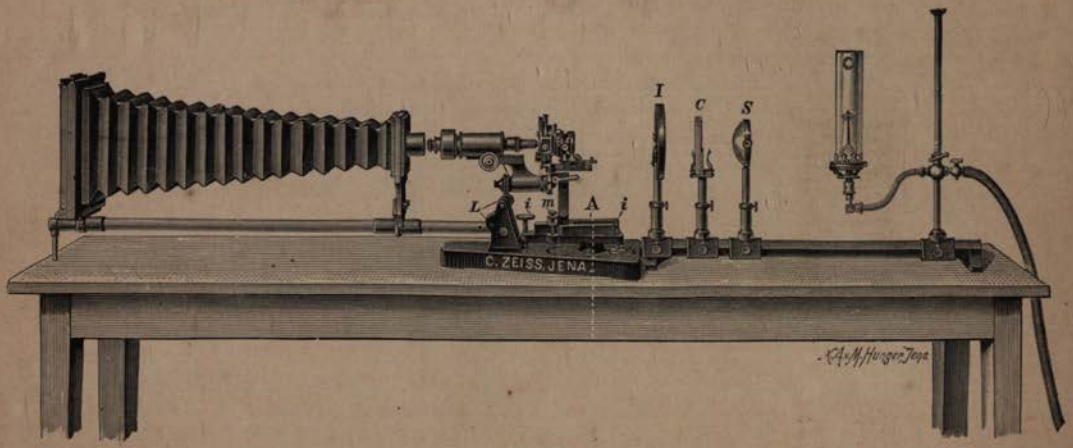


Fig. 29.

using new materials, MM. Zeiss have succeeded, not only in perfecting the images given by these lenses, but also in diminishing the price, and in guaranteeing their perfect durability.

MULTIPLE COLOUR ILLUMINATION.

Julius Rheinberg.

IT is the natural desire of all who possess a microscope to look at their objects to the best advantage. For those who employ the microscope in the pursuit of science, it is a necessity, and for those who use it as a pastime it is equally pleasurable to know that they are seeing as much as can be seen, given their particular object and their particular lenses.

Now what is the secret of doing this? It lies simply in the mode of illumination, and I purpose in this article to treat of some comparatively new methods of illumination particularly calculated to show up numerous classes of objects to great advantage, and which at the same time give very pleasing effects.

It is now some five years since I first began to make experiments with a view to finding out how it might be possible, without staining, to cause an object and its background to appear of different colours, and so secure a greater contrast than usual. Up to the present I have found three different ways by which we can make uncoloured objects assume any colour we wish, and our background any other colour. In many circumstances we can also make definite parts of objects themselves assume different colours—if so desired. These effects may be produced so simply that any amateur may make many of the experiments himself at the cost of a few pence.

In all microscopes fitted with a condenser in the substage, there is, underneath the condenser lenses, a ring or some form of holder to take stops for dark-ground illumination. Now let us cut out a disc of red gelatine (such as is used for crackers) to fit this ring, then punch a hole in the centre about a third of its diameter, and stick over the hole a piece of blue gelatine of the same size (fig. 1a). Then we place this colour disc in the holder under the condenser,* and use it in the same way as we would use the dark-ground stop.† We will suppose we are using a 1" objective. The result to those who have not seen it before will be astonishing. The objects, for instance a slide of Polycystina, or some living Rotifers, will appear perfectly red, and the background perfectly blue. The great contrast throws the objects up in a most striking manner. Of course, if we wish to vary our colours, all we have to do is to vary the colours of the gelatine; a yellow disc with a blue centre will show the objects yellow on a blue ground, an uncoloured disc with a green centre (fig. 1b) will show the object white or whatever may be its natural colour on a green background, and so forth. We must take care, however, in making the discs that the central spot which gives the colour to the background is comparatively darker than the other part of the disc.

Now we will vary the experiment and make a disc like fig. 1d, of four sectors; the two opposite ones red, the other two blue, and on it paste a black

*An Abbe condenser with the top lens removed is the most suitable.

†Even without a condenser we may make the experiment, by fixing a bull's eye or plano-convex lens at a short distance beneath the object (the exact place must be determined by trial) plane side upwards. The colour discs are then simply laid upon the plane surface.

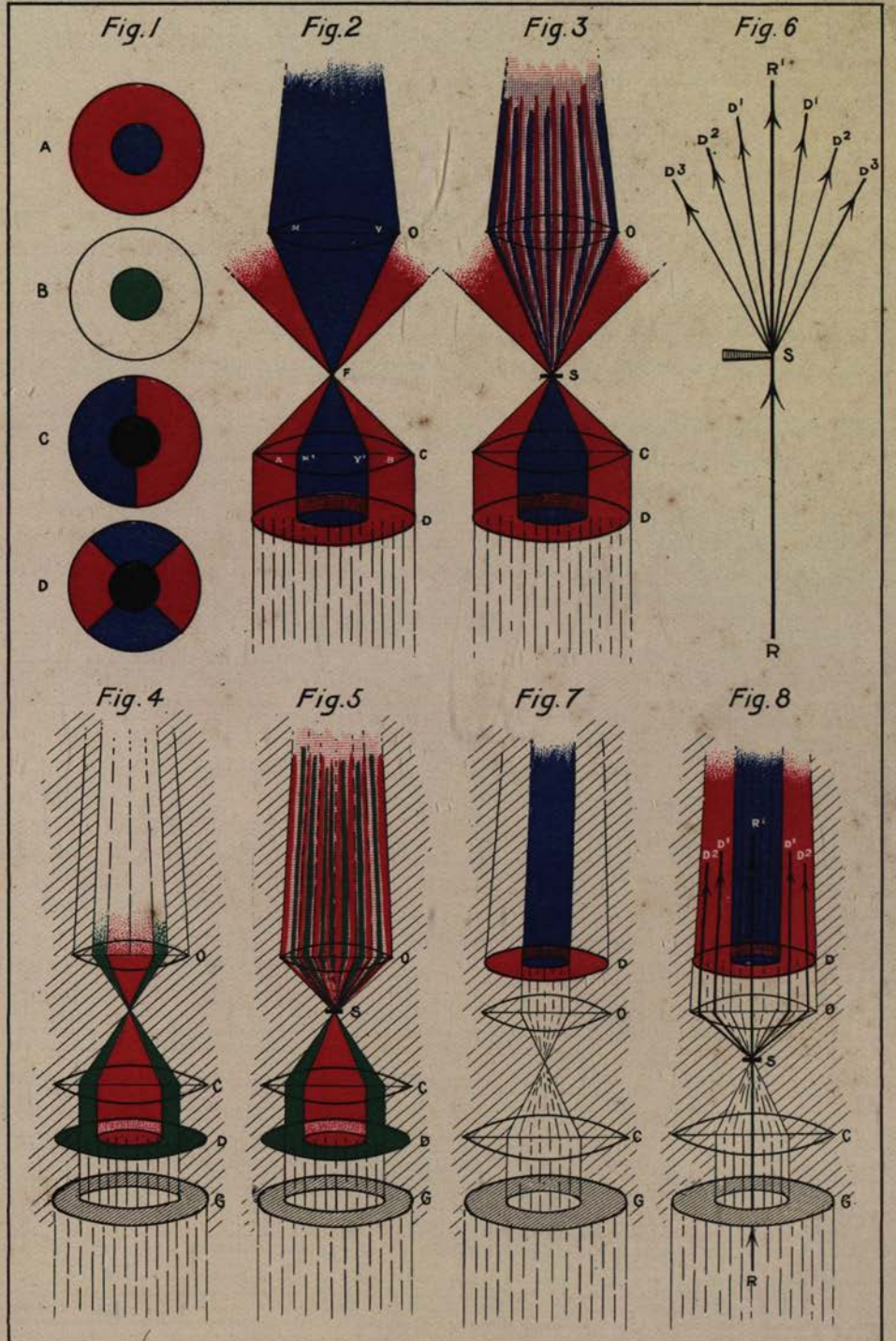


Fig. 1
A
B
C
D
Fig. 2
M
V
O
F
A
M'
V'
B
C
D
Fig. 3
O
S
C
D
Fig. 6
R'
D'
D'
D2
D2
D3
D3
S
R
Fig. 4
O
C
D
G
Fig. 5
O
S
C
D
G
Fig. 7
O
O
C
G
Fig. 8
V
R'
D2
D'
B'
D2
D
O
S
C
G
R

central spot. Using the disc we will look at a small piece of silk mounted in Canada balsam (a morsel of a Japanese silk handkerchief does excellently) and notice the result: It is as if the silk had been woven in two colours—all the horizontal threads composing the warp being blue; all the vertical ones which form the weft being red.

Having made these experiments let us stop and consider the cause of these rather startling results. Why did the object ostentatiously appropriate to itself all the red light, and why did the background appear blue only when we used the disc like fig. 1a? The answer to the last question is simply that without having an object in the field no red light gets into the microscope tube, because the cone of light admitted by the 1" objective is no larger than the cone of light coming from the condenser through the blue central portion of the colour disc, as seen in fig. 2.

The expressions, viz:—"Aperture" of an objective or condenser, and "Cone of Light" admitted by an objective or condenser are of somewhat frequent recurrence in this article. It may be useful to some readers to have these terms explained, an exact comprehension being essential to understand the subject. When we use a condenser we bring the light which passes through it to a focus on the object; and the shape of the passage of light is a cone with its apex at the object and its base the condenser lenses. The cone is represented by the triangle FAB of fig 2. After passing the focus the light again forms a cone, inverted this time, and the whole or some part of this cone may be taken up by the objective (FXY fig. 2). The cone may be wide or narrow; for instance the cone FXY is relatively narrow to the cone FAB. As a matter of fact, condensers are always made of large "aperture," i.e., they are always made to give a large cone of light, and it is usual to narrow them down when desired by an iris diaphragm. But objectives are made of fixed "apertures" which differ very greatly, according to the power of the objective, a low power like a 1" objective having an "aperture" much smaller than a $\frac{1}{6}$" objective for instance—or, to put it in other words, the "cone of light" admitted by a 1" objective is relatively small as compared to that admitted by a $\frac{1}{6}$".

Now as regards the object, there was light knocking up against it from all sides—partly blue light, partly red—and as we may for our purpose regard an object as a collection of little prisms of various shapes, which turn and twist the light falling on them in various directions according to the laws of refraction and reflection, we can easily see that a lot of this light which hit the object, had its direction changed so as to fall within the cone of light admitted by the objective. So that plenty of the red light, which would otherwise have passed outside of the objective, has now been thrown up into it by the object, and depicts the object in that colour in consequence. Fig. 3 illustrates this. Of course this has not prevented the blue light also forming an image of the object in blue, but you will notice that the difference in *area* between the red and blue portion of the disc (fig. 1a) is considerable, in fact the former is about eight times as great as the latter, and as a consequence the red image will be roughly speaking about eight times as strong as the blue one, which causes the latter to be swamped out as far as the eye is concerned.

We will now proceed to a different method of illumination. The above method was limited to the use of objectives of not higher power than $\frac{1}{3}$", but the illumination now to be described, as well as the third method, is applicable to all objectives, no matter of what power.

We will suppose we are looking at some diatoms with a $\frac{1}{6}$" objective, and we will put a colour disc below the condenser as before, one with a red centre and a green rim this time. The red centre should be of ruby-coloured gelatine, which can be easily obtained, but the particular green gelatine for our purpose is difficult to get, and the best thing to do is to buy a little of the stain known as malachite green, dissolve it in alcohol, and then add a little of the dissolved stain to some collodion. A little of the dyed collodion should then be poured over the ordinary green gelatine, which can be bought ready. It quickly evaporates, leaving a thin film of the gelatine of a beautiful blue-green colour such as we require.

It is a well-known fact that white light is made up of light of all colours, and that by means of a prism the rainbow colours can be re-combined to form white light. It has also been practically demonstrated by Ives, the inventor of the photochromoscope, how three so-called fundamental colours, viz., green, red, and blue-violet, can be re-combined so as to appear white. But it is not so generally known that, if correctly chosen, two colours only are needed to give the impression of white light to the eye, when combined in the proper ratio. Such however is the fact, and this is the principle we are going to work with. If we can mix the ruby-red light of the central portion of our colour disc with the green colour of the rim in the right proportion, we can obtain light the colour of which to our eye appears almost white. Now the mixing of these colours is exceedingly simple, provided our condenser has an iris diaphragm to it.

Let us look down the microscope with the iris quite open, then the field or background appears quite green, for this time we are using an objective of wide aperture, one which will admit a cone of light much wider than that proceeding from the central red portion of the disc only, and as already pointed out, when there is a large excess of light of one colour over that of another colour, the stronger swamps out the weaker. We now gradually close the iris diaphragm, thereby shutting out more and more of the green light, the colour of the background will then be seen to change to a fainter and fainter green and a point will be reached where it appears neutral tinted or almost white.* Fig. 4.

Not so, however, the object; on this white ground the diatom shines forth resplendent in the hues of red and green more or less undiminished in intensity, the ridges and higher structures appear green, the other parts red. For it is clear enough that the different parts of the diatom will not have the red and green light falling upon them or be throwing the light up into the objective in the precise ratio to form white light. The ridges catch a deal more oblique light, which happens to be green, and much of the finer and more transparent structure catches and passes up an excess of red light in the objective. Again, wherever there are very fine perforations or holes in the shells of the diatoms these appear pure red, because so very little of the obliquely falling green light passes through the holes

*If we continued closing the iris the field would of course change from the neutral tint to a pure red, as soon as all the green light had been shut out.

into the objective, and thus to the eye. This enables us to say at a glance and with certainty, that such and such spots are perforations in a membrane, whilst others are small raised prominences, etc., things which in the ordinary way it is exceedingly difficult to determine, and upon which many controversies have been held.

For the best effects with the kind of illumination just described (which fig. 5 illustrates diagrammatically), the total utilized cone of light from the condenser should fill from two-thirds to three-quarters the aperture of the objective. The way to see whether this is the case is to take the eyepiece out of the microscope and look down the tube, then we can see the back lens of the objective, and to what extent its aperture or area is filled with light.

Now we will proceed to the third method of multiple colour illumination—one which depends upon a quite different set of principles to the other two, viz., on the class of phenomena known as diffraction. But, as before, we will let practice precede explanation. We take some small microscopic cover glasses of the thinnest kind, choosing them of such a size that we can drop them from above on to the back lens of the objective which we are about to use, say a $\frac{1}{6}$" or $\frac{1}{8}$" objective. They must, of course, completely cover the back lens. We transform these little cover glasses into colour discs by coating them with stained collodion, for gelatine such as we used for the discs placed under the condenser is not nearly sufficiently clear and homogeneous for the present purpose. The best way to make the stained collodion is to dissolve the dye (fuchsine, methylen blue and malachite green are suitable dyes) in pure alcohol, and then add it to the collodion, which may be bought ready. I would, however, strongly recommend those who wish to make the experiments also to make their own collodion by dissolving a little of Schering's celloidin in equal parts of ether and alcohol. This gives very much better results than the ordinary ready-made collodion. With a pipette or a glass rod we drop the dyed collodion on the little glass circles and let it evaporate, which it does very quickly. Then with a needle we scratch the film off the glass except where it is required. If we want to make a red disc with blue centre, we coat the one side of the glass with a red, the other side with a blue film. All the blue excepting a small central spot about one quarter the diameter of the top lens of the objective is then removed, and on the red side the film is scratched away from the central area to correspond.

Having dropped our little disc into the objective, we first focus the latter on to our object, a section of bone, let us say, or if preferred, we may look at diatoms again, as there is nothing to compare with these for experimental purposes. Then we remove the object, and carefully focus our condenser on to the same plane. If the condenser is properly focussed, the back lens of the objective should be filled with light when the eyepiece of the microscope is taken out and we look down the tube. Next, we close the iris diaphragm of the condenser, looking the while down the tube, till all the light is cut off from the red part of the disc, and only just fills the blue central part (fig. 7). Now we can replace the eyepiece, bringing the object in position again, and the object will appear clearly and distinctly red on a blue ground, and we shall notice that the diatoms appear to stand out almost stereoscopically, and that the thicker parts of

he bone section, which appear hazy if looked at with the same objective without colour disc, have become much better defined. Of course with a colour disc having a blue central spot without the red rim, the object shows up in its natural colour on a blue ground. *Vice versa*, if the disc is completely blue with only a central spot uncoloured (the size of which, however, must not exceed one-sixth to one-eighth part of the diameter), the object shows up blue on an uncoloured ground.

The diffraction of light passing by and through the object is the chief cause of our results in this instance. Without going too deeply into an explanation of diffraction, which would involve discussing the laws of wave motion, I need only mention that whenever a ray of light* (R, fig. 6) meets an obstacle (S, fig. 6) this point becomes a centre for waves to spread out from. Now the crests and hollows of all the waves of light produced at this point and in the immediate vicinity intermingle and interact on one another, and thereby become regulated in such a way that one portion of the light, R', travels on undisturbed as a continuation of the original ray, whilst other diffracted rays (D1, D2, D3) are produced (differing only from the last-named one in that they are not quite so luminous), which proceed from the point of the obstacle at various angles to this direction. The whole forms what is known as a diffraction fan.

In ordinary vision we need take but little account of these diffracted rays, but in vision with optical instruments and especially with the microscope they play a large and fundamental part, for one of the functions of the objective is to collect these rays, starting from a point of the object at different angles, and bring them altogether back into one focus at that spot where an image of that particular point of the object is formed. A peculiarity about diffraction fans is that the smaller the structure which causes them, the more spread out are the component rays of the fan, and that at least two rays must be taken up by the objective to show up the structure at all, except as a sort of indefinable blur.

To return to the colour discs, we can now comprehend how any ray (R, fig. 8), gets split up into the rays R1, d1, d2; the first one of which passes through the blue part of the disc before being brought to a focus up near the eyepiece, the others through the red part of the disc. The greater number get the best of it and so the most of the structure appears in red. Of the whole object, only the very coarse structure would appear in blue, because the rays of the diffraction fan produced by this are so crowded together that they all pass through the blue centre of the disc.

Incidentally I may say that by having colour discs ground in a peculiar manner, it has been found possible to get the separate images of an object formed by the blue and red portions of a colour disc side by side, the one of which shows only the coarsest structure, the other all the finer structure.

Refraction of light also plays some part in determining the colour of the object in this third method of illumination, but having dealt with this already in the other methods, I may leave it to the reader's own observation how it acts here.

* The ordinary expression "Rays" of light, it should be noted, is an abstract term which is used for convenience and stands for the direction in which undulations of light may be travelling.

It is curious to observe that in this method we have employed a comparatively very narrow cone of light from the condenser, with an objective of large aperture, just the exact reverse to what we did in our first method.

That in this method the colour of the background is simply determined by the colour of the only light which gets into the microscope-objective, when there is no object placed in the path of the light rays (to wit, blue in our example), stands to reason (fig. 7).

It only remains for us now to see where the use of multiple colour illumination comes in, and what is its scope. For the *pretty* results thereby obtainable, though very good in their way, and calculated to call forth expressions of delighted surprise from our non-microscopic friends, are not the most worthy object of the microscopist's ambition. To see a ruby-red rotifer disporting itself in a deep green sea, to look at muscle fibres with alternate red and blue bands, in short, to see our objects highly coloured, like the Lord Mayor's Show, what is the use?

The use may be summed up by saying that we increase our knowledge of the object by,

1. Increased ability to see it.

2. Increased ability to draw conclusions from that which we see. When we go out on a sunny day in the country, we put on a broad-brimmed hat, so that the light of the sun may be kept from our eyes, and we can see the landscape better. If we want to see particularly well we even shade our eyes further by holding our hands up to the brim. That is just what we usually do not do when we look through the microscope, for we gaze at the full glare of our light, and if it is too strong we merely shut some of it off without stopping to distinguish between, or to consider whether, it is image-forming or background-forming light; nevertheless we expect our eyes to distinguish all they might be capable of doing.

Again, if we go and take the train, we observe the signal-boxes fitted with red and green lights which long experience has shown that the engine-drivers can distinguish most readily. But in using the microscope we do not usually trouble about the sensitiveness of our eyes to colours; in other words, we are much too apt to forget that whilst our eyes are very sensitive optical instruments, we must pay due regard also to their physiology. This then is the keynote to the way in which multiple colour illumination acts in sharpening the vision. We get greater perception of detail, of depth, and of solidity or general form.

At the same time knowing how we have arranged our coloured lights to fall upon our objects, and noticing which parts are lighted up in the various colours, we are able to draw additional inferences as to their size—even in matters of wave lengths—as to their shape, and as to whether what we see is the true object, or a false light effect, for such may frequently occur with bad illumination, and have caused innumerable discussions. It is a lesson in microscopic optics in itself to study the appearance of air or oil bubbles in water with different kinds of multiple colour illumination, and I may safely say that most readers who experiment with these kinds of illumination will know considerably more about their microscopes after than before.

The scope of multiple colour illumination is a large one; it lends itself well to the study of botanical and physiological preparations,* to the study of living organisms, to investigations on diatom structure, to commercial purposes, as examining fibres, papers, etc., and to photo-micrography.

It has been my endeavour in this article to convey an idea as to the methods and theory of multiple colour illumination in an intelligible mannner, without going too much into technicalities, and those who are sufficiently interested in the subject, I would refer to my papers in the journal of the Royal Microscopical Society of 1896, pp. 373-88, and in the *Quekett Club Journal*, 1897, p. 346, and 438.

EXPLANATION OF DIAGRAMS.

Fig. 1. Various Colour Discs.

Fig. 2. First Method of Multiple Colour Illumination—No object in the field.

Fig. 3. First Method of Multiple Colour Illumination—Object in position.

Fig. 4. Second Method of Multiple Colour Illumination—No object in the field.

Fig. 5. Second Method of Multiple Colour Illumination—Object in position.

Fig. 6. Diffraction Fan produced by a ray of Light R passing by or through an obstacle S.

Fig. 7. Third Method of Multiple Colour Illumination—No object in the field.

Fig. 8. Third Method of Multiple Colour Illumination—Object in position. D, Colour Disc; C, Condenser; S, Object; O, Condenser; G, Iris Diaphragm.

Dotted vertical lines represent the passage of white light.

Slanting shading represents dark space.

*I ought perhaps to mention here that multiple colour illumination does not come into competition with the staining of objects, as the purpose of this is selective absorption of colouring substance according to their chemical constitutions.

ON SURFACE ANTARCTIC DIATOMS.

By Henry Stolterfoth, M.D.

THE study of the lowest forms of vegetable life will always be an attractive one to the microscopist. In the case of diatoms, not only have they the most beautiful siliceous skeletons, but they are the most widely distributed of all microscopic objects. Given water, or even moisture, you will find living diatoms, and moreover there are vast deposits of these minute forms both on the land and at the bottom of many seas and fresh-water lakes.

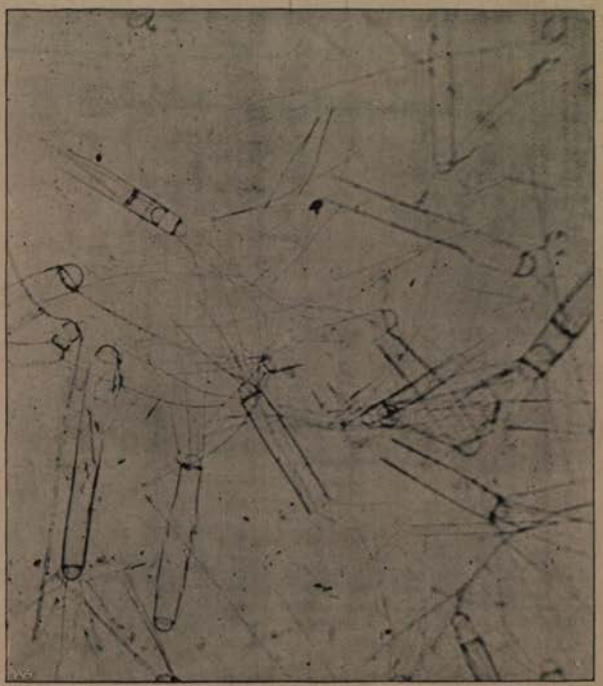


Fig. 1.—Corethron criophilum. Cast. (Magnified 150 diameters)

In the Arctic regions, where all other forms of vegetable life disappear, you will still find diatoms, and the important part played by them is well shown in Nansen's *Farthest North*, Vol. I., p. 39. The labours of Prof. Cleve, of Upsala, furnished Nansen with one of his strong arguments for the drift of the "Fram" across the Polar sea, and his words are well worth quoting:—"These diatoms "are decidedly marine—i.e., take their origin from salt water—with some few "fresh-water forms which the wind has carried from land. The diatomous flora "in this dust is quite peculiar, and unlike what I have found in many thousands "of other specimens, with one exception, with which it shows complete con- "formity, namely, a specimen which was collected by Kellman during the Vega

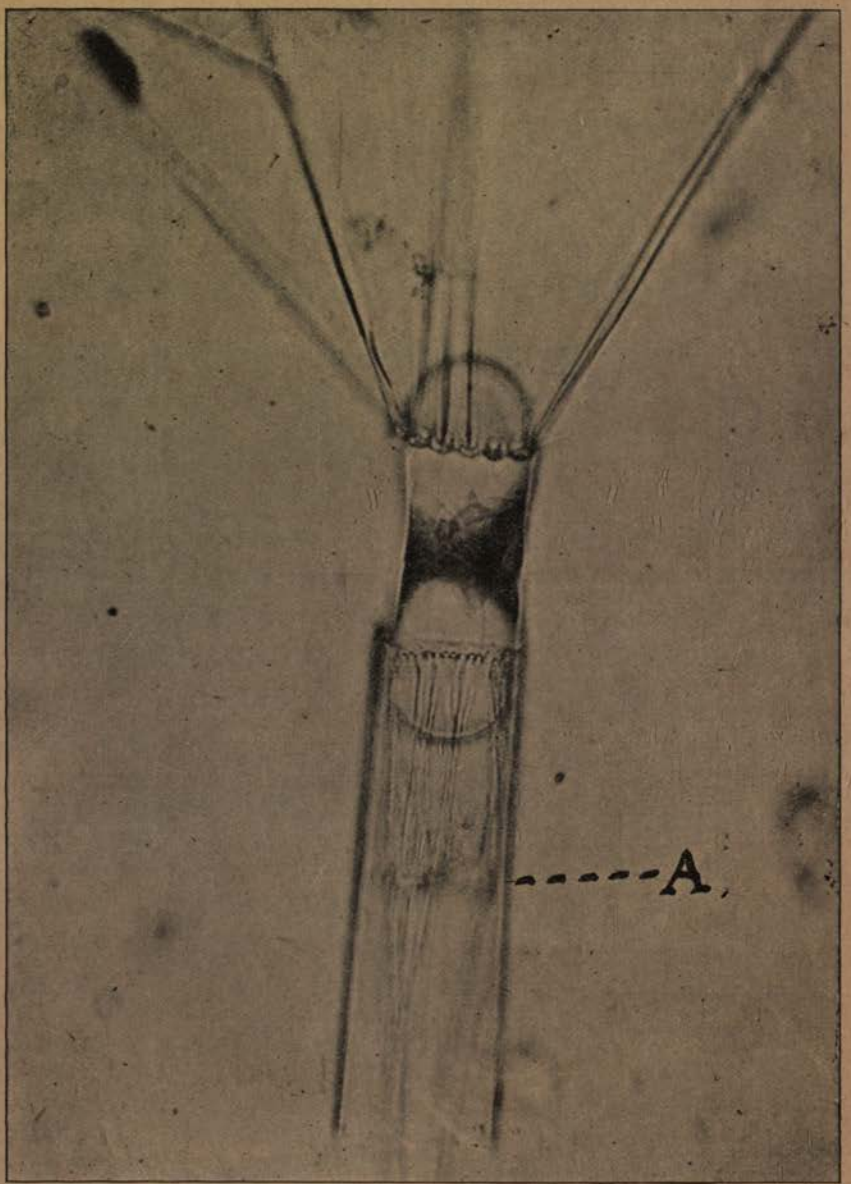


Fig 2—Corethron criophilum. Cast. (Magnified 600 diameters.)

" expedition, on an ice-floe off Cape Wankeren, near Behring Straits. Species " and varieties were perfectly identical in both specimens. Cleve was able to " distinguish sixteen species of diatoms. All these appear also in the dust from

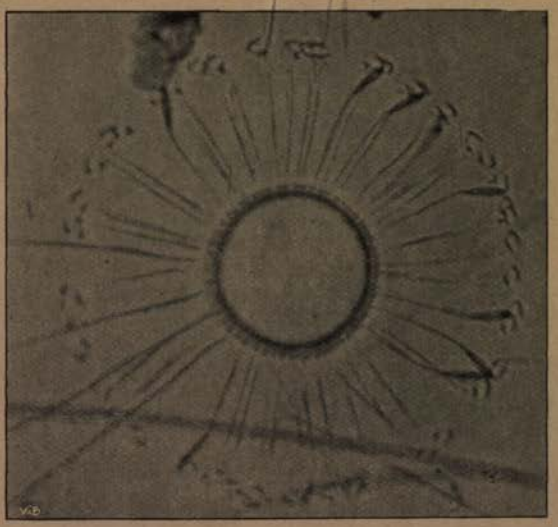


Fig. 3.

" Cape Wankeren, and twelve of them have been found at that place alone, and " nowhere else in all the world. This was a notable coincidence between two " such remote points, and Cleve is certainly right in saying: ' It is indeed quite " remarkable that the diatomous flora on the ice-floes off Behring Straits, and on

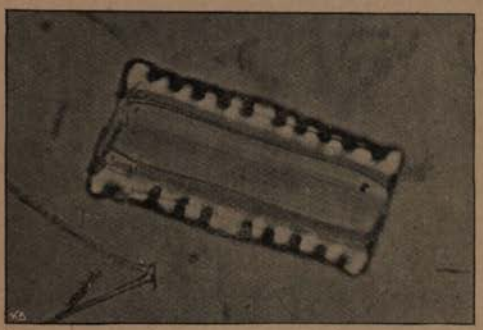


Fig. 4.

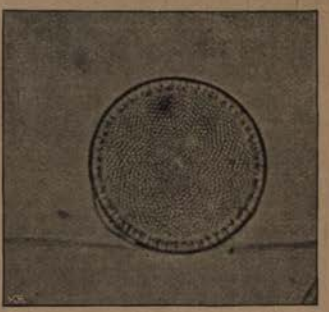


Fig. 5.

" the east coast of Greenland, should so completely resemble each other, and " should be so utterly unlike all others. It points to an open connection between " the seas east of Greenland and north of Asia. Through this open connection

"(I continued in my address) drift ice is therefore yearly transported across the "unknown Polar Sea. *On this same drift ice, and by the same route, it must be no "less possible to transport an expedi-"tion.*'"

Fig. 6.

From this we see that the Arctic diatoms have been carefully examined by Prof. Cleve. Not so, however, with the Antarctic forms. Now that men's minds are turned to the investigation of the South Pole, it is well to enquire what is known about these unexplored regions, and naturally we again turn to diatoms. There are two ways of examining the diatomous flora. First, we have the forms living on the surface; secondly, the dead siliceous skeletons which cover the bottom of the ocean.

The first Antarctic surface diatoms I ever examined were from the "Challenger," which, in its voyage from the Cape of Good Hope to New Zealand, passed south of Kerguelen Island to S. Lat. 67°, E. Long. 80° to 100°, and made several deep-sea

Fig. 7.

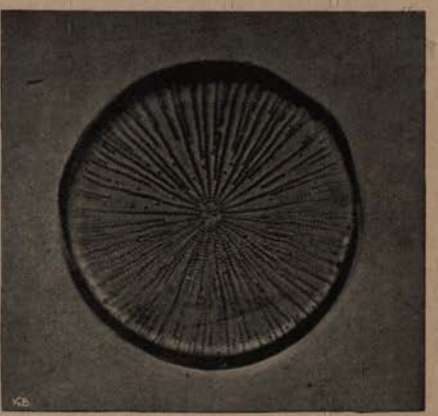


Fig. 8.

soundings, bringing up material from the bottom. In the "Proceedings of the Royal Society," Vol. XXIV., there is a map of the ocean bottom,

on which is marked "Diatomaceous ooze"—an area more than half the size of Australia. I have examined this ooze, and many of the forms are given in Count Castracane's Report of the Scientific Results of the Voyage of H.M.S. "Challenger," Vol. II., Botany. At the same time a few surface gatherings were made. It will not be out of place to describe shortly how these surface gatherings are made. A bag of sailcloth about three feet long and one foot wide is attached to a hoop. This hoop is fastened by four cords to a rope, and this is dragged in the water after the ship or boat, either keeping it at the surface or a few feet below. After it has been dragged for a certain time it is drawn up, turned inside out and washed in a jar or pan of pure water—this water must be allowed to stand some hours in the dark, when the surface water is poured away and the sediment put into bottles for preservation. This simple process for collecting diatoms I have used for many years, and it is applicable to either fresh or salt water. In the case of salt water, it is sufficient to add half spirit as a preservative. I can strongly advise all those who have the opportunity to use this method, as many rare forms of diatoms may thus be collected. At the seaside and on our own coasts we can hardly go out in a boat without finding in our tow-net that most wonderful of all diatoms, Bacillaria Paradoxa W Sm, and many others. I had for examination only one "Challenger" surface dredging. This is described in the Royal Society's Report, and one of the new forms is figured

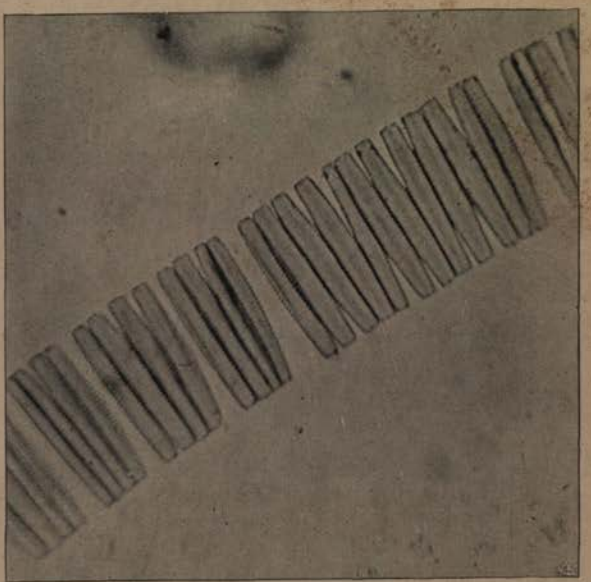


Fig. 9.

which consists of bundles of twisted rods. It is unnamed, and may be only portions of an undescribed Corethron. I have in my own collection several slides of this particular gathering. In the year 1894 I received from Prof. D'Arcy Thompson eleven small bottles of surface gatherings from the Antarctic Sea, made from a ship that sailed from Dundee, partly for whaling, partly for scientific work. These small bottles proved most interesting. They had no latitude or longitude marked on them, but the forms showed that they must have grown in some locality where huge icebergs were melting. And here, exactly as Prof. Cleve has remarked, we find many fresh-water forms mixed with the brackish and salt-water species. My own idea is that many of these icebergs are portions of fresh-water glaciers which break off from the land and gradually melt, forming a lake of fresh-water in the midst of the sea. I received eleven small bottles in all, marked:

(Xa 1893) (2C. 12.1.93) (2D. 30.1.93) (2G 31.1.93) (2K 13.12.93) (2L) (2Q) (2R) (2E) (*192 Donald) (2I).

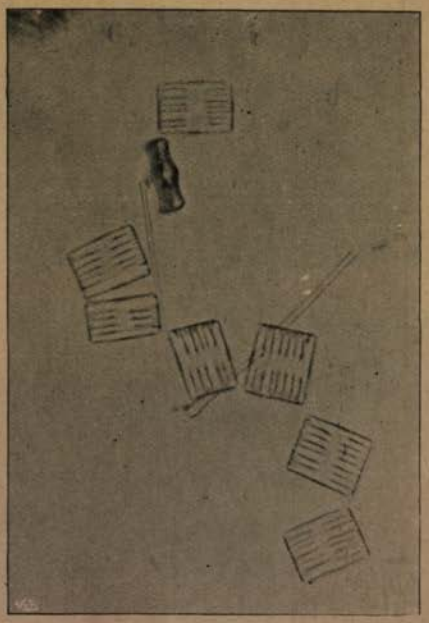


Fig. 10.

These were all marked Antarctic, and in some cases had dates which show that they were made in the midsummer of the South Polar regions—namely, December and January. I first washed away by decanting, all traces of salt water and spirit, and as a preliminary I burnt the forms on a platinum spatula on the glass cover. I then mounted them in balsam. By this process you get the forms less broken up than by any other plan. I also boiled some of them in acid to get rid of the protoplasm and other vegetable debris, so as to study their minute siliceous structure. I will now go through the different bottles *seriatim*.

1. (X a 93). I should have taken this, had I not been otherwise informed, for a surface gathering made on an English lake. In fact, it is very like a surface gathering made on Windermere. The form that at once atrracted my attention was Asterionella formosa, var: gracillima Grun; we also find Pleurosigma hippocampus W. Sm, Cyclotella compta Ehr, Fragilaria-capucina Desm; and many other fresh-water diatoms that are common to this country. I cannot help thinking that this gathering was made in a calm summer sea, as very little motion would soon break up the spiral arrangement of Asterionella or the delicate film of Fragilaria. It is just possible that the gathering may have been made on a pool located on an iceberg, but the bottle tells me nothing. The bottles (2C) (2D) and (2G) resemble each other much, and all contain abundantly a form I had never seen before, which has only been seen figured from fragments by Castracane. Fig. 1 shows a general slide burnt on the cover glass, and from a study of this plate, which is a photograph from the slide, a good idea may be formed of the growth, and how fresh bundles of setœ or bristles are being formed in the tube before a fresh valve is produced. In Fig. 2, at the

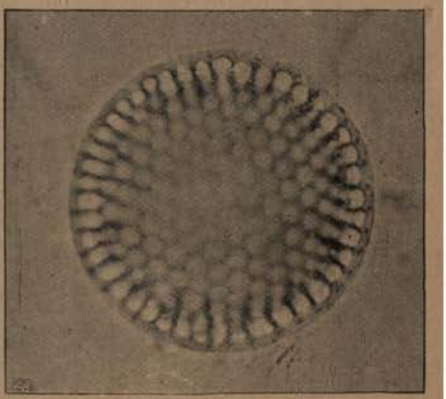


Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

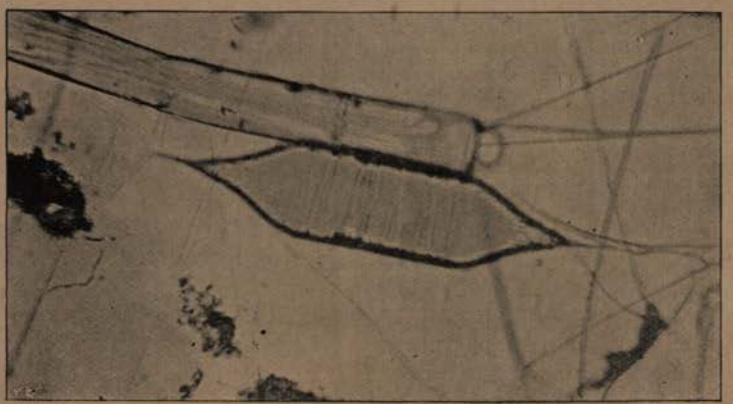


Fig. 15.

point marked A, there is a dark rim, and in a slide which has been cleaned in acid this dark rim is spread out and is shown in Fig. 3. These appear to be hooks, and their only use seems to be to keep the longer setœ together in the tube. This diatom seems to be purely a surface form, and the bristles help to keep it floating. The two bottles marked (2 K) and (2 L) are almost clean gatherings of Rhizosolenia setigera Brightw: and appear to be identical with what are found in the estuaries off our own coast. The four bottles marked (2 Q) (2 R) (2 E) and (2 I) contain chiefly Corethron and Chœtoceros, and a few others. The bottle marked (* 192 Donald) contains many forms of Rhizosolenia, but very few specimens of Corethron. Having reviewed the different gatherings generally, I will give a list, with photographs of the rarer forms which I have found in these eleven bottles, and which may be of use to those who at some future day may have other Antarctic gatherings to examine.

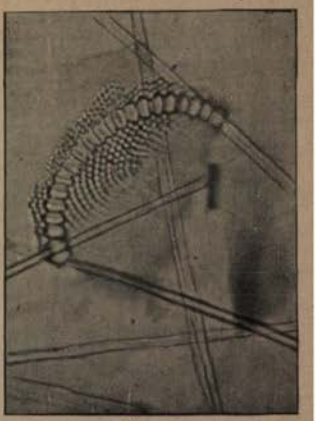


Fig. 16.

Fig. 4. Eunotogramma varabile Grun.
,, 5. Coscinodiscus tuberculatus Greg × 500.
,, 6. ,, ,, ,, × 150.
,, 7. Molleria Antarcticus Cast: this is probably the same as Eucampia Zodiacus W. Sm.

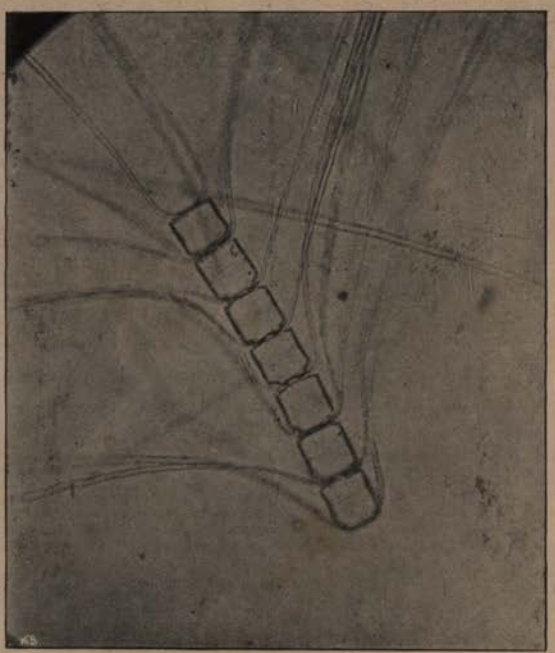


Fig. 17.

Fig. 8. Coscinodiscus notabilis Rat.
,, 9. Fragilaria linearis Cast.
,, 10. Tabellaria flocculosa Kutz.
,, 11. Stephanopyxis turris var Arctica Grun.
,, 12. Rhizosolenia inermis Cast.
,, 13. ,, polydactyla Cast.
,, 14. ,, sima Cast.
,, 15. ,, Antarctica, N.S.
,, 16. Brightwellia Murrayii Cast.
,, 17. Chœtoceros criophilum Cast.
,, 18. ,, Atlanticus Cleve.
,, 19. Hemiaulus, new species.

The few forms I have selected are full of interest, and will, I think, be new to many of my readers. If I had only known the exact localities in which these

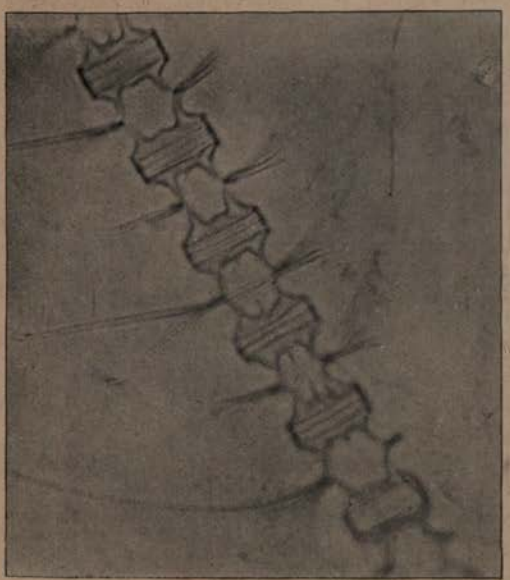


Fig. 18

Fig. 19.

gatherings were made, my paper would have been more complete and interesting. One word as to the illustrations: they were taken from the roughly-mounted slides, and all that can be said of them is that, being photographs, they represent truly what was on the slide, and will, I hope, prove sufficient for the purposes of identification.

THE VALUE OF THE MICROSCOPE FOR VETERINARY PURPOSES.

By Professor Hobday. F.R.C.V.S.,
Royal Veterinary College, London, N.W.

PERHAPS in no sphere of medical science has the use of the microscope been extended during the past ten or fifteen years with greater ardour than in that of the veterinary surgeon. The strides which have been made are so great as to be almost incredible; indeed, the modern veterinary surgeon considers the microscope almost as essential as the scalpel.

In the college, as a student, he makes its acquaintance during his first year, when desiring to acquire an intimate knowledge of the structure of the parts forming the bony skeleton, whilst during the second, third, and fourth periods of

*Fig. 1. Showing one of the varieties of Mange parasites of the horse. ×58.

*Fig. 2. Showing Tubercl Bacilli from horse's spleen. ×1000.

study it is his daily companion for the recognition of facts connected with histology, pathology, and the history of the numerous parasites which cause so many of the diseases which he will afterwards be called upon to treat.

Without its aid in certain diseases treatment would only be empirical, and thus carried on in the "hit or miss" style of the old cow leech and farrier. As an aid to clinical diagnosis it is invaluable, especially for the recognition of malignant tumours, parasites, and micro-organisms; by its use many of the diseases of man and animals have been proved to have a common origin, and to be produced by identically the same organisms.

By way of illustration, let us take the case in which an animal is suffering from the presence of tumours in some part of the body; the removal of these

* For the plates I am entirely indebted to Professor McFadyean, M.B., B.Sc., M.R.C.V.S., Dean of the Royal Veterinary College.

growths may or may not give complete restoration to health and vigour, and were it not for the microscope it would be impossible to say accurately whether or not, if the growths be excised, a cure would result. With a knowledge of the pathological appearances, all that has to be done is to remove the whole or a portion of one of the tumours, prepare it in a certain way, make sections and place them on the microscope stage.

With the skin parasites, too, diagnosis is much simplified by microscopical examination; for example, take what is commonly called "mange" in the dog. In the dog there are two varieties of parasite which give rise to this disorder—viz., the *sarcoptis canis* and the *demodex folliculorum*. For the latter no certain permanent cure is known, and treatment is only undertaken in animals of great value, whilst the cure of the other is a comparatively simple matter. During a certain period of "mange" it is often a matter of doubt even to an expert in canine work, to say with absolute certainty from which the animal is suffering, particularly as some of the non-parasitic skin diseases also give rise to somewhat

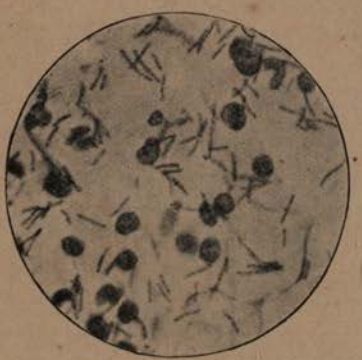


Fig. 3. Showing Anthrax Bacilli from spleen of ox. ×1000.

Fig. 4. Showing Glanders Bacilli from a culture. ×1000.

similar clinical manifestations. When a certain stage has been reached, the microscope can be brought to bear upon the point and a definite decision given.

Similarly in the horse, one variety of mange is not very difficult to get rid of, whilst another causes a lot of trouble.

Now with reference to micro-organisms—and these, of course, are now recognised to play a very important part in the causation and spread of disease—it is almost entirely owing to microscopical research that their presence has been demonstrated. The micro-organisms which cause actinomycosis, or "wooden tongue," in cattle, scirrhous cord and certain other inflammatory growths in the tissues of the horse, tetanus, tuberculosis, anthrax, glanders, swine fever, and a host of others, would never have been revealed to us had it not been for the microscope, proving conclusively that its use and results are of the utmost importance and value, not only to the profession but also for the protection of the public at large.

What, for instance, would become of the agricultural community, or indeed of the whole nation, if such diseases as anthrax were allowed to devastate our herds without recognition or restriction, and particularly is the danger greater in the case of those diseases which are communicable to man. Enormous expense to the Government, and certainly ruin to the breeders of animals, must result.

With, however, the microscope as an aid to clinical symptoms, recognition is simplified and made certain, and protective measures can at once be adopted.

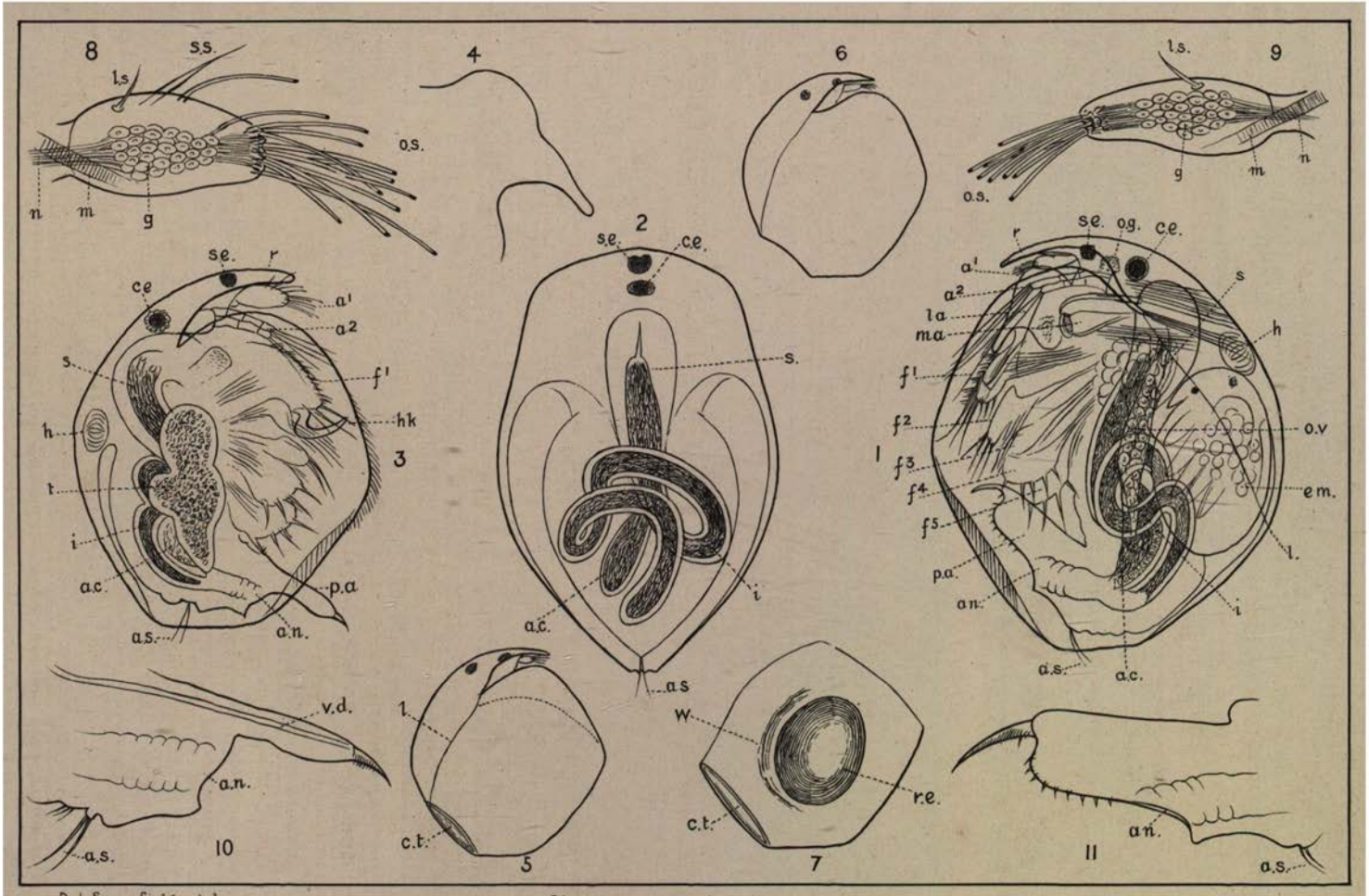
Veterinary science owes to this instrument a great debt of gratitude, and it is only by utlilizing the means placed at our disposal to the fullest extent that we can ever hope in any way to repay it.

A VERY COMMON WATER-FLEA.
(CHYDORUS SPHÆRICUS).

By D. J. Scourfield.

IN spite of the fact that the subject of this short sketch is one of the commonest of those exceedingly common little aquatic creatures, the Entomostraca, being, indeed, absolutely the commonest of the division Cladocera, it is probably but very imperfectly known to the vast majority of even those microscopists who devote themselves to the collection of pond-life. This is due in part, no doubt, to the comparatively small size of the animal (maximum length, ½ m.m.), but in a larger degree to the general lack of interest taken in the study of the whole group in this country at the present time—a circumstance which cannot be denied, although much to be regretted. Perhaps the following remarks, by showing something of what is already known and indicating a little of what is still unknown with regard to a species which can be obtained everywhere and at all times, may serve to awaken a little sympathy, if not exactly enthusiasm, for our "common" water-fleas, and especially, it is hoped, for the smaller forms, which have necessarily been most neglected.

As already mentioned, *Chydorus sphæricus* belongs to the Cladocera, which is one of the three most important groups of the Entomostraca, the other two being the Ostracoda (*Cypris*, *Candona*, etc.) and the Copepoda (*Cyclops*, *Diaptomus*, etc.). Its position in relation to its allies may best be shown, perhaps, by giving the families into which the order (or, more strictly, sub-order) Cladocera is now divided, together with a few of the best known examples of each.



D·J·Scourfield del.

Chydorus sphæricus.

CLADOCERA.

Fam. 1.	Sididæ,	e.g. *Sida crystallina.*
„ 2.	Holopedidæ,	e.g. *Holopedium gibberum.*
„ 3.	Daphnidæ,	e.g. *Daphnia pulex, Simocephalus vetulus.*
„ 4.	Bosminidæ,	e.g. *Bosmina longirostris.*
„ 5.	Lyncodaphnidæ,	e.g. *Macrothrix laticornis.*
„ 6.	Lynceidæ,	e.g. *Eurycercus lamellatus, Peracantha truncata, Alona quadrangularis,* *CHYDORUS SPHÆRICUS.*
„ 7.	Polyphemidæ,	e.g. *Polyphemus pediculus.*
„ 8.	Leptodoridæ,	e.g. *Leptodora hyalina.*

The family Lynceidæ, of which *Chydorus sphæricus* may be considered almos a typical representative, comprises animals which are, on the average, very mucl smaller than those of any of the other families except the Bosminidæ. Morpho logically, these forms are in general distinguished from the others, especially fron the Daphnidæ, by (1) the very prominent rostrum, (2) the constant occurrence of three joints to each branch of the second (swimming) Antennæ, and the possession by the latter of only seven, or at most eight, swimming bristles, (3) the comparatively large size of the simple eye which often equals and sometimes exceeds the compound eye; (4) the coiled intestine together with the absence of anterior cæca and presence of an anal cæcum, (5) the position of the anus on the dorsal edge of the post-abdomen at some considerable distance from its extremity, and (6) the small number (two as a rule) of ordinary or "summer" eggs placed at one time in the brood cavity.

The above-mentioned points, it will be seen, are very well illustrated by fig. 1 on the accompanying plate, which is a lateral view of the form of *Chydorus sphæricus* usually found—i.e., of the female producing the so-called "summer" eggs. This figure also shows, of course, a considerable number of further details, and, if taken in conjunction with fig. 2, which is the dorsal view of a similar animal, will give a fairly good notion of the appearance and organisation of this form without the necessity for a lengthy description. There are one or two features, however, which seem to deserve special notice. Thus, as regards general outline, it should be observed that although the animal, as seen from the side, is remarkably well rounded, being almost circular in some specimens, there are a couple of minute characteristics which separate it from nearly all the other members of the genus. These are the angulated ventral margin and the truncated posterior margin. As seen from behind (or in front) the outline is extremely broad in comparison with most of the other Lynceids, but it is very typical of the genus *Chydorus*, the flattening of the head being especially characteristic. A second point that may be referred to is in relation to that portion of the shell which may be termed the head-shield (cephalostegite of Huxley). This, it will be seen, not only protects the head, but extends considerably more than half-way down the back. Its anterior portion, ending in the sharply-pointed rostrum, is normally very closely approximated to the shell-valves, and as it is also to some extent movable, it can be brought down so as to actually touch the anterior margins of the latter. In this way the animal can shut itself in its shell almost as completely as an Ostracod, and there can be no doubt that this is at times of

the greatest importance as a protection against enemies and even against moderate desiccation. As regards the internal structure, the most striking features are the coiled intestine and the large anal cæcum. There is only one remark that I wish to make about the former, and that is that the coils always proceed from the right side of the animal to left, and never *vice versa*. This rule is constant throughout the Lynceidæ, so far as I have observed, with the exception of *Eurycercus lamellatus*. The anal cæcum demands a little more attention. It is, if one may judge from its large size in this and many other species, a very important organ, but its functions are at present problematical, and further observations are badly wanted in this connection. It consists of a roughly triangular sac possessing very delicate walls, except dorsally, where large glandular cells occur. It is constantly dilating and contracting, but the former movement is rather slow and may easily be overlooked. During dilatation water is taken in through the anus, and it is not improbable that one of the functions of this curious organ may be of a respiratory nature. But the cæcum also serves as a temporary receptacle for the fæces which seem to be invariably passed into it from the intestine before being finally ejected from the body.

Leaving the ordinary, or parthenogenetic female, a few words may now be devoted to the very much rarer "ephippial" female, so called because it is the homologue of the form which, among the Daphnidæ, produces the structure known as the "ephippium." It is the sexually mature female, and produces the so-called "winter" or resting eggs, which, unlike the "summer" eggs, require fertilisation in order to develop. This form can usually be distinguished at once by the naked eye, or with a pocket lens, owing to its dark colour. Under the microscope it is seen that the darkening is not uniformly distributed, but that it is greatest in the posterior dorsal portion of the shell. The outline of the latter (see fig. 5) is practically the same as that of the ordinary form, but owing to an extraordinary thickening of the chitin along the posterior third of the back, there is seen in that region what appears to be a highly refractive spindle-shaped body (*c.t.*). In addition to the foregoing outward differences, the "ephippial" female also exhibits differences in relation to the ovaries. These produce (one at a time) eggs of a quite different type to the "summer" eggs, and by a peculiar process, the details of which cannot, however, be given here. Soon after the extrusion of one of these special eggs into the brood cavity, the "ephippial" female undergoes a moult and the egg becomes lodged in the thrown-off shell. The head-shield soon parts company from the rest of the shell, and then the anterior portions of the valves break off along a line of weakness indicated by the dotted line in fig. 5. The egg with its covering now appears as in fig. 7, though very much darker than shown, and is ready to undergo the vicissitudes of frost or drought or foreign travel. Compared with the highly evolved "ephippium" which is formed by the Daphnidæ for the protection of their resting eggs, the arrangement in *C. sphæricus* (and other species of the Lynceidæ) is manifestly very primitive, and although both are fundamentally the same, I would suggest that the simpler structure be distinguished as a proto-ephippium.

So far as concerns the production of the proto-ephippium and the actual formation of the resting egg, the "ephippial" female is quite independent of the male, but if the resting egg is to be released from the ovary it is necessary that

fertilisation should take place. At least this is the general rule among the larger forms of the Cladocera, as shown by Weismann, and the following facts seem to show that it is true in this case also. Two females with the outlines as shown in fig. 6, and with rudimentary resting eggs in the ovaries were isolated for observation. In three days both had moulted and then appeared as in fig. 5, i.e., as typical "ephippial" females. The resting eggs in the ovaries, were also much larger. In three days more the animals had moulted again and appeared as at first. The resting eggs, however, had not been placed in the thrown-off proto-ephippia which were quite empty. In a further three days another moult took place and the animals carried proto-ephippia for a second time. These were thrown off three days later but again without the eggs, which still remained in the ovaries. After a further six days, the animals remaining without change, the observations were discontinued. As touching the necessity for fertilisation, the foregoing is only negative evidence, it is true, but as the facts are pretty conclusive in other cases, there is little doubt but that it was the absence of a male which caused the apparently wasteful phenomenon of the production of proto-ephippia time after time without the resting eggs leaving the ovaries.

In company with the "ephippial" females there are probably always to be found, if searched for, a few at least of the rare males of the species. A lateral view of one of these is shown in fig. 3. The male is always somewhat smaller than either of the forms of the female, measuring only about $\frac{1}{70}''$, and it is also readily distinguished from them by the following peculiarities :—(1) The more angulated shell, (2) the blunt rostrum, (3) the larger Antennules, (4) the prominent hook on each of the first pair of feet, (5) the peculiar post-abdomen, and (6) the testes. Two of the foregoing characters are worth considering briefly. First, the male Antennule (fig. 8) is not only relatively but absolutely larger than the same appendage in the female (fig. 9), and it possesses a greater number of special sense hairs. In the female the tip of the antennule is furnished with nine hyaline setæ—the so-called olfactory setæ—each with a little refractive pellet at the extremity, and at the base a little chitinous bead imbedded in the antennule. The number nine, it may be explained in passing, is apparently constant among the females throughout the whole of the Cladocera with the exception of the families Polyphemidæ and Holopedidæ. The male of *C. sphæricus* has twelve such setæ on each antennule, and there is also present a special seta having the proximal half very strongly chitinised. The little pointed lateral seta is the same in both sexes.

The other characteristic of the male to which attention may be called is the post-abdomen (fig. 10). This differs from that of the female (fig. 11) very markedly, being only about one-third of the breadth of the latter and completely destitute of teeth on the dorsal edge. The terminal claws are also reduced and are without the basal teeth, although the fine lateral hairs are still present. Now the peculiar feature about this male post-abdomen is that in the stage prior to the adult, it is exactly similar, both in shape and armature, to that of the female, and the whole of the changes take place therefore at a single moult. The openings of the double vas deferens are near the bases of the terminal claws. The whole arrangement of the male post-abdomen shows quite plainly that it is employed

to introduce the spermatozoa into the brood cavity of the female, although, so far as I know, this has never been actually observed. The spermatozoa it may be mentioned are exceedingly minute spherical bodies devoid of movement.

Having now disposed of the few structural and physiological points selected for special reference, a little space may be given to a couple of biological questions connected with the species under consideration.

First, as regards distribution and some allied phenomena. As becomes an animal which is evidently one of Nature's fit ones, *C. sphæricus* is not only very much at home in these islands, but appears to thrive in most parts of the world, for in addition to its generally recognised commonness over the whole northern circumpolar land area, it has already been recorded from several localities in the southern hemisphere. As a general rule this species prefers pieces of water of small or moderate size with plenty of aquatic vegetation, but so great is its power of adaptation to surroundings that it may be found in almost every conceivable situation. The place where it is least likely to be found is out in the clear water of large and deep lakes. Under some circumstances, however, it may be found even here, as Apstein and others have shown. The chief condition necessary for this pelagic habit seems to be the presence in the water of such algæ as *Clathrocystis*, to the comparatively large colonies of which it no doubt clings when tired of swimming and upon which, as they disintegrate, it can readily feed.

The times and causes of the occurrence of males and "ephippial" females, and the concomitant production of resting eggs, is another subject which dare not be left out of any account, however short, of this species. My own experience has been that, considered as a whole, this species exhibits two periods of sexual activity each year, one in April and May and the other in November and December, the former being decidedly the most important. But it must not be supposed that all the colonies of the species are affected in the same way. It is, on the contrary, almost certain that many colonies never have a sexual period at all or only at very long intervals. This has been testified to again and again, and it is the only way in which I can explain the fact that several of the ponds that I have searched most thoroughly have never once yielded a male or "ephippial" female. Again, of the two periods mentioned, the earlier affects as a rule only those individuals which live in tiny pieces of water likely to be dried up in the summer, whereas towards the close of the year it is the colonies living in moderate-sized ponds which sometimes produce the sexually perfect individuals.

The factors leading up to the sexual periods, in this and other species of Cladocera, have not yet been satisfactorily determined. At first sight it seems plausible to believe that the direct action of unfavourable surroundings, such as the gradual drying up of a pond, the gradual fall in temperature and such like, should automatically cause the colonies affected to produce the individuals which alone have the power to form resting eggs, and so save the species from extinction. But Weismann has shown, both theoretically and experimentally, that there are very considerable difficulties connected with this view of the matter, and he advances the explanation that the

production of sexually mature individuals depends upon the inner constitution of the species, and further that it is connected with definite generations. Even this idea, however, is not by any means satisfactory, and the fact remains that notwithstanding the really marvellous work of Weismann in this connection, we have not yet got to the bottom of this matter. In conclusion I would heartily recommend any one wishing to know of a piece of original work worth doing, and within the power of an earnest amateur, to take up the study of this question of the times and causes of the appearance of males and "ephippial" females among the Cladocera. And further, as a special object of attention in the enquiry to recommend to his notice the very common little water-flea, *Chydorus sphæricus*.

EXPLANATION OF PLATE.

CHYDORUS SPHÆRICUS.

Fig. 1. Side view of ordinary (parthenogenetic) female, × 130.
„ 2. Dorsal view of „ „ „ × 130.
„ 3. Side view of male, × 130.
In the three foregoing figures the shell-sculpture, which consists of very fine but quite distinct hexagonal markings, has been omitted for the sake of clearness.
„ 4. Chitinous plate attached to Labrum.
„ 5. Outline of "ephippial" female.
„ 6. „ „ „ after throwing off the "proto-ephippium."
„ 7. Resting egg enclosed in "proto-ephippium."
„ 8. Antennule (1st Antenna) of male.
„ 9. „ „ female.
„ 10. Post-abdomen of male.
„ 11. „ female.

a^1 First Antennæ.
a^2 Second „
a.c. Anal cæcum.
an. Anus.
a.s. Abdominal setæ.
c.e. Compound eye.
c.t. Chitinous thickening.
em. Embryo in brood cavity.
f^1-*f*^{5} Feet (5 pairs).
g. Ganglion.
h. Heart.
hk. Hook on first pair of feet of male.
i. Intestine.
l. Line of junction between head-shield and carapace.
la. Labrum.
l.s. Lateral seta.
m. Muscle.
ma. Mandibles.
n. Nerve.
o.g. Optic ganglion.
o.s. Olfactory setæ.
ov. Ovary.
p.a. Post-abdomen.
r. Rostrum.
r.e. Resting egg.
s. Stomach.
s.e. Simple eye.
t. Testis.
v.d. Vas deferens.
w. Wrinkle in shell membrane surrounding resting egg.

SOME POINTS IN THE HISTORY OF BACTERIOLOGY AND ITS APPLICATION TO MODERN MEDICINE.

By W. C. C. Pakes, D.P.H. (Camb.), F.C.S., etc.

WITH the death of M. Pasteur, the birth and infancy of bacteriology have become history. She no longer toddles about with the uncertain steps of childhood, but walks along with the proud consciousness of healthy adolescence. Her influence on medicine and sanitary science has been enormous. She has revolutionised the methods of surgery and converted the paradoxes of the last generation into the truisms of to-day. The diagnosis and treatment of disease falling more and more into the hands of the bacteriologist. Every year, diseases which were thought to be due to bacteria are being proved to be so, so adding not only to our knowledge of disease, but to our powers of prevention.

Although the term bacteriology strictly speaking means the science of bacteria, the bacteriologist interests himself in all micro-organisms, whether animal or vegetable.

Micro-organisms are divided into two classes: those of vegetable and those of animal origin. Those of vegetable origin are further divided into three, the moulds or hypomycetes, the yeasts or blastomycetes, and the bacteria or schizomycetes.

Bacteria may be conveniently divided into three sub-divisions: bacilli or rod-shaped organisms, cocci or spherical bodies and spirilla or corkscrew-shaped organisms.

The cocci are further sub-divided into staphylococci, streptococci, sarcinæ, tetragena; whilst the spirilla include vibrios (or parts of the corkscrew) and spirochæta or corkscrew drawn out.

As long ago as 1671, Kircher and Lange expressed the opinion that the purpura of lying-in women, measles and other fevers were due to worms and animalculæ. A few years later Leeuwenhoek made the first microscope worthy the name, and was able, by its aid, to describe minute living and moving bodies hitherto unseen. He examined water, stools, saliva, etc., and spoke of the various forms of bacteria. Andry, as the result of his work, evolved a germ theory of putrefaction and fermentation which gained such credence that the mercurial treatment which was then introduced, was so exploited for the purpose of killing these germs.

Pleuciz, a Viennese doctor, even went so far as to insist upon the specific character of the infective agents, and in corroborating Linnæus' observations came to the conclusion that putrefaction was the result of the growth of micro-organisms. This, owing to the imperfect methods of the time, he was, however, unable to prove.

The next important step was the attempted classification of these organisms by Müller of Copenhagen, who also described what are now known as spores.

Needham, as the result of his experiments, believed in spontaneous generation: Spallanzani criticising the experiments, upheld the view that the methods of sterilising were faulty, or that the organisms, which he thought were in the air, had got into Needham's flasks. In 1836 Schulze contrived an apparatus which completely disproved the spontaneous generation theory.

With 1837 begins the history of modern bacteriology. It had been shewn in the previous year that meat infusions when sterilised could be kept from putrefaction, and from this time onward the great abiogenetic controversy waxed hot. In this year Cagniard, Latour and Schwann announced that the yeast cells described by Leeuwenhoek, found in grape juice, etc., were the cause of fermentation; and Bassi described a form of yeast which produced a disease in silk worms. In 1840 appeared upon the scenes a man who, by his talents and labours, has put the study upon a firm scientific basis—M. Pasteur. He entered the arena on the side of the anti-abiogetitists, and for years he was pitted against that great chemist Liebig. It would take too long to recount how, inch by inch, he cut the ground from under Liebig's feet and finally brought the scientific world to the side opposed to spontaneous generation.

All the work hitherto undertaken had been on most unsatisfactory lines, as it was almost impossible to obtain pure cultivations. Pasteur soon found out that certain organisms flourished best in distinctive media. For instance, that in saccharine solutions, yeasts grow better than the putrefactive bacteria, and he took advantage of this fact by sowing the yeasts in this medium in order to get rid of the other organisms, and in this manner was able to prove that sour beer and muddy beer were caused by yeasts which he termed "wild" yeasts. At best this was a long and difficult process, and Klebs, as an alternative, proposed the method of dilution. Having an impure culture he diluted the broth with sterile water and examined it under the microscope to determine how many organisms were contained in a single drop. If now such a drop contained 10 bacteria, he added one drop to 10 c.c. of sterile water, and taking 10 flasks of broth, inoculated each with 1 c.c. of his diluted solution. If he happened to have one organism in each c.c., as theoretically he should, all his flasks contained growths; but he generally found that some flasks showed no growth, and consequently he could not definitely point out which of the remainder contained the result of the increase of one organism. It was not until Koch introduced broth rendered solid by the addition of gelatine that researchers were able to satisfy themselves that they were really dealing with pure cultures. When, later, agar-agar, blood-serum and potato came into general use the study was made easier and more satisfactory.

Whilst the controversy as to the relations between yeasts and fermentation, and bacteria and putrefaction were being fought, the kindred question of bacteria as the cause of disease was also discussed. In 1850, Davaine, working at Anthrax, was able to discover a bacillus in the blood of all animals dying of splenic fever. He then experimented with a large number of rabbits, injecting healthy ones with a drop of blood drawn from one dead of the disease. He was able to give as many as one hundred animals the disease successively. Organisms were also found in other maladies, such as certain skin diseases, septicæmia, pyæmia, quarter-evil and symptomatic anthrax.

In 1876 Koch succeeded in cultivating the anthrax bacillus, and demonstrating the spores, whilst subsequently Pasteur was able to sub-cultivate it through several generations and then kill rabbits with the cultivated bacteria. He also found that under certain conditions the bacilli could be rendered non-pathogenic.

From this time our knowledge has increased by leaps and bounds. The knowledge of the life history of the bacteria led to the discovery of the poisons they produce—the toxins. The production of the toxin again paved the way for the anti-toxins and so on. Now-a-days a student with average intelligence and a little practice can diagnose several diseases with certainty by the application of the microscope and test tube.

Various media are used for the growth of bacteria, among which are broth, nutrient gelatine, nutrient agar, blood serum, potato and milk.

Broth is a solution of meat extract in water to which peptone and common salt have been added. In order to obtain a solid medium, gelatine or agar is added to the broth. Gelatine is used when the bacteria are to be grown at the room temperature, i.e., 20°C. Agar possesses the property of remaining solid at a much higher temperature than gelatine, even as high as 40°C. Milk and potato are the natural substances. Blood-serum is the clear serum which separates from ox or sheep's blood after it has been allowed to coagulate.

Before using these media it is necessary to be certain that no organisms are present in the prepared substances, and in order to ensure this, it becomes essential to put them through the process of sterilisation. As the addition of any disinfectant would prevent the growth of the organisms we want to study, as well as killing the organisms which we do not want, it is evident that they cannot be used. Heating them is the only means at our disposal.

All the glass vessels are sterilised by placing them in what is known as the hot-air steriliser, and allowing them to remain at a temperature of 150°C. for half an hour to three-quarters of an hour. The media themselves are sterilised by placing them in the steam steriliser for twenty minutes on each of three successive days, taking care that the steam is *streaming*. The reason for this elaborate sterilisation is that spores are generally present, and they are very much more difficult to destroy than the bacteria themselves.

Among the enormous number of bacteria there are a few which are the causes of disease in man and the lower animals. These fall into three classes: 1st, those which are pathogenic to man only, or, rather which only produce natural diseases in man; 2nd, those which only produce natural diseases in the lower animals; and 3rd, those which produce diseases in both.

Organisms may be pathogenic in various ways. By pathogenic, we mean causing a condition which is not compatible with the idea of perfect health. They may give rise to a small pimple on the skin which is slightly painful, but which gives rise to no dangerous symptoms: they may be the cause of a more extended local inflammation which becomes then painful. They may give rise to a distinctly local inflammation, but at the same time produce powerful poisons which are absorbed into the system and give rise to very dangerous symptoms; or they may be present in the blood and tissues, and so alter the whole conditions of these as to render life impossible. There is still a further way by which bacteria are able to

injuriously affect us, and that is by growing in our food and producing poisons of a different nature than those mentioned above, the ingestion of which is sometimes fatal. The bacteria which produce these latter poisons are generally innocuous themselves.

When an organism is accepted as the cause of any disease some or all of certain conditions should be fulfilled.

1st.—The organism must be sufficiently distinctive and always present in the patient suffering from the disease.

2nd.—It should be capable of growth outside the body.

3rd.—The inoculation of pure cultures into the body or blood of an animal must produce symptoms similar to those characterising the original disease.

The first of these conditions must of course be fulfilled. If the second were absolutely essential, some diseases, which are accepted as being due to micro-organisms would still remain non-proven. For instance Leprosy, all attempts have as yet failed to grow this bacillus outside the body. Malaria in man and Coccidiosis in rabbits would also fall into the same category.

* * *

The tubercle bacillus is one of the most important organisms with which we have to deal. It is the active cause of many diseases both in man and in the lower animals. In a man it is found causing a large number of different pathological conditions, as for instance consumption, inflammation of the lining membranes of the brain, inflammation of the bowels, and peritoneum, curvature of the spine, lupus, and diseases of the eye, kidney, hip-joint, throat, etc.

The bacillus is one which is somewhat easy to identify but difficult to cultivate. Of all the various bacteria which have been described only three have been found to have the same staining reactions. These are the tubercle, leprosy, and smegma bacilli. The great majority of bacteria stain well and easily with some of the aniline dyes. These three do not stain so readily, but when they are stained they do not part with their colour so quickly as do the remainder of bacteria. This fact is taken advantage of in trying to identify any of these three organisms. Suppose that it is necessary to see if any tubercle bacilli are present in a specimen of sputum. The sputum is spread in a thin layer on a thin cover-slip and allowed to dry in the air. When it is dry it is passed three times through the flame of a Bunsen burner in order to coagulate the albuminous material, and so fix the specimen to the cover-slip. The slip is now placed in a small vessel containing what is known as carbol-fuchsin; the fuchsin is warmed until the steam just begins to rise, and the slip is allowed to remain in the stain for about five minutes. It is now taken out and washed well with water. If the specimen were now mounted and examined under the microscope it would be found that everything on the slip was stained; instead of mounting, it is dipped in a mixture of strong sulphuric acid, one part, and water three parts; the colour will be seen to turn at once a pale yellow; the slip is again washed well in water, and if it has been long enough in contact with the acid, the preparation will have a faint pink colour. If now the slip be examined under the microscope, the whole of the

groundwork will be found to be of a pale red colour. Before mounting permanently, however, it is customary to dip the slip in another stain, carbol-methylene blue for three seconds, in order to colour the groundwork of a different colour than the bacilli which we want to find. After the slip is washed for the last time in water, it is allowed to dry and is then mounted in Canada balsam on a clean slide. The reason for all these different treatments is as follows :—The first staining with carbol-fuchsin colours everything on the slip; the 25 % sulphuric acid almost instantly removes the colour from everything except the tubercle bacilli; these latter will sometimes resist the action of the acid for as long a time as ten minutes, whereas the rest of the organisms and the tissue elements are certainly decolorised within thirty seconds. After these have been decolorised they are again stained with the blue in order the more easily to find the small red rods under the microscope.

The tubercle bacillus, as has been said, is not easy to cultivate outside the body, and like many other organisms, the more virulent it is the more difficult it is to cultivate. When it is at all virulent it does not grow on the ordinary media which have been mentioned before; it is necessary to add glycerin to these media in the proportion of about six per cent. Even on glycerinated media the growth is much slower than most other organisms, and this fact makes the isolation of the bacillus from other bacteria difficult.

If, therefore, it is suspected that a patient is suffering from a tuberculous disease and no tubercle bacilli can be found, it is customary to inoculate a susceptible animal such as the guinea-pig, and to await events.

Until recent times it was considered that consumption and other tuberculous diseases were hereditary. Of late years, however, it has been forced upon the scientific world that this is by no means so certainly the case, and the disease is now classed with the rest of the specific fevers. This is a step in the right direction because it makes people take precautions which they would not otherwise take. Perhaps one of the reasons why the fact is not more widely appreciated by the people generally is that the disease is a very chronic one, and the period of incubation is slow and uncertain. Added to this is the fact that the bacilli may obtain entrance into the body and lie dormant for months or even years, and spring into activity after some enfeebling illness. How often do apparently healthy children succumb to tuberculosis in some form or other after measles and whooping cough, and adults after typhoid fever!

The sooner that tuberculosis is recognised by the public as an infectious disease the sooner will it be possible to try to eradicate it. One has only to see the reckless manner in which those suffering from consumption spit about in rooms, 'buses, etc., to realise how great is the danger to which we are all exposed. The Brompton Hospital for Diseases of the Chest issue very wise directions for the guidance of their patients, and it would be well if all such institutions would or could do the same.

There is yet another danger to which we are all to some extent, and young children to a much greater extent liable, and that is contracting the disease from cattle. A large percentage of all the herds in the United Kingdom suffer from

tuberculosis; this means that both the meat and the milk are from time to time infected with the bacilli.

Several experiments made for the Royal Commission on Tuberculosis shewed that ordinary cooking does not destroy the bacilli, and consequently, when we eat underdone meat we may be allowing the germs to gain access into our bodies. If butchers were always careful in the selection of the beef and in the killing of the animals all might be well. The prosecutions which are instituted every now and then, however, shew that they are not by any means careful. Milk purveyors also are not always beyond reproach. Cows occasionally suffer from tuberculosus disease of their udders; when this is so the tubercle bacilli gain access to the milk. As milk is rarely boiled, owing to the peculiar flavour that it has, the bacilli are simply drunk with the milk. The writer has himself examined a sample of milk which at a low computation contained one million tubercle bacilli to the pint, and this milk was actually being drunk by a considerable number of people.

The previous attempts to produce a curative for, or preventive against this dread disease have not been very successful. Koch's latest extract is yet on its trial and it remains to be seen whether it will be successful.

* * *

Diphtheria is a disease that is almost entirely confined to man. The only other animal in which it is found is the cat. This probably accounts for a certain number of cases in children which cannot be otherwise accounted for.

The disease is in the early stages characterised by an exudation upon the throat which is at times so tenacious that it can be peeled off and appears as a definite membrane. In this exudation are the bacilli. Generally they cannot be found elsewhere, and although one observer claims to have isolated them from various organs, other observers have failed to do so. In children whose air passages are narrow, the amount of exudation is sometimes so great that the air passages are blocked up with it, and the children are suffocated from want of air. If this were the only danger of diphtheria, the disease would not be so fatal as it is, for the operation of tracheotomy would save perhaps the majority of those so affected. But this is not all, the bacilli in their growth, elaborate a powerful toxin as well as a ferment, both of which are absorbed into the blood. The ferment continues to produce more of this toxin, and at length there is so much in the system that it begins to poison the patient. The especial actions are—first, weakening the heart; and second, causing paralysis of certain muscles. The action of the heart is the more important, for it is so great that if the patient has even a small amount of exertion, he is liable to die immediately from heart failure.

In order to diagnose this disease a little of the exudation is removed from the throat and smeared on the surface of an inspissated blood-serum tube. This is kept at a temperature of 37°C. for about eighteen hours, and then from it a cover-slip preparation is made *secundam artem* and examined under the microscope. If the exudation be examined it may be possible to find the bacilli, but two facts militate against the possibility. First, the bacilli are not so typical in appearance from the exudation as from the blood-serum; and second, there will be many more bacteria of other kinds on the preparation from the exudation direct, as

most of these will not grow on the surface of the blood-serum in so short a time as will the bacillus of diphtheria.

The mortality of this disease has been greatly reduced since the introduction of the diphtheria antitoxin. This antitoxin owes its discovery entirely to bacteriology and to vivisection. It was found that if an animal were given doses of a bacillus which were not sufficient to kill it, increasing doses could be given to it, until it can stand a dose enough to kill several animals. At this moment the serum of this animal has the property of neutralising the pathogenic properties of the bacilli when introduced into other animals; so that if enough of the bacilli to kill an animal were introduced into its system, and at the same time a small quantity of the serum of the animal which has been immunised against the bacillus, the inoculated animal would not die. One fact was noticed which has a very direct bearing upon the treatment of the disease, that if the bacilli were injected a considerable time before the serum, the animal died. This seems to show that when the toxin is once well-established in the body, the antitoxin has not so much power for good. The obvious inference is to inject the antitoxin as soon as the possibility of diphtheria is diagnosed. It is held by a few that the antitoxin may do harm, but this is so unlikely, that it is better to give the antitoxin to a patient who has not got diphtheria than to omit to give it early to a patient who subsequently proves to have the disease.

* * *

Typhoid fever is a disease which attacks the rich and poor alike, and is one which is transmitted by direct contact, by water and milk.

The bacillus of typhoid fever is known as the bacillus typhi abdominalis, or bacillus typhosus. It is an organism which is easy to grow but difficult to catch. It is by no means an easy thing to get the bacillus from the dejecta of patients known to be suffering from the disease, although they are almost certainly there. In the urine, however, it is possibly more easily found, but too late to be of much use in diagnosis.

Until quite recently, this organism has been confounded with two other groups of organisms, those belonging to what are known as the "Coli" and "Enteritidis of Gärtner" groups respectively. Recently, however, several fresh tests have been applied which have brought out the differences to such an extent that the chance of mistaking them is more remote.

There is no doubt that many of the old observations regarding the discovery of the bacillus of typhoid fever in fæces, drinking water, etc., were not correct, the observers having mistaken the bacillus coli communis or the bacillus enteritidis of Gärtner for this organism.

In order that an organism may be said to be the bacillus typhi abdominalis, it should possess the following characteristics:—

It must be an actively motile bacillus.

It must produce no indol when grown in broth.

It must produce no gas when grown in glucose media.

It must not clot milk at 37°C.

It must produce a slight amount of acid in lactose solutions.

It must produce thin spreading sulcate colonies on gelatin plates.

It must produce an almost invisible transparent growth on potato.

In addition to these tests, there is yet another which was introduced by Gruber and Durham. That is that it must shew what is known as a clumping reaction when mixed with the serum of an animal immunised against the typhoid bacillus. The introduction of this test has done three things. First, it has enabled us to determine the identity of the bacillus with more accuracy; second, it has made more certain the connection between the bacillus and the disease; and third, it has given us another test for the disease.

If the serum of an animal rendered immune against this organism reacts, i.e., causes the bacilli to clump when it is mixed with them, it appears obvious that if typhoid fever is caused by this organism, the serum of a patient suffering from the disease might also react. Widal was the first to publish a series of cases shewing that this was so, and the reaction, as I think wrongly, goes by his name. The reaction itself surely belongs to Gruber and the application of it to Widal.

The reaction itself is obtained in the following way. A small quantity of blood is collected from the ear of the patient and allowed to clot; the clear serum is then obtained in a pipette and is ready for use. An 18 hour-old broth cultivation of the bacillus typhi abdominalis is prepared and mixed with the serum, in definite proportions. There are various ways of diluting the serum, differing only in the details. Some experimenters use 10%, others 5% or even 2% and 1%. All agree that it is useless to use the undiluted serum, because many normal people may give a reaction.

In considering the value of the reaction in the diagnosis of typhoid fever, it must be remembered that the test is essentially a quantitative one and not merely a qualitative one. The serum of normal people will not react when it is dilute, and it would appear that when the serum forms under 10% of the mixture, only that derived from those suffering from typhoid fever will then react. On the other hand, patients suffering from uudoubted typhoid fever, will not always give a reaction. Many cases are on record where the serum has given no reaction until the tenth day of the disease; other cases are also on record where the strength of the reaction has varied considerably in the same patient from time to time. The reaction persists for some time after convalescence; the majority of patients will give the reaction as long as two years after the disease, some have given it as long as six and even ten years after.

When, therefore a patient is suffering from a disease which is supposed to be typhoid fever, and we wish to clear up the diagnosis by the application of this test, it becomes necessary to know, first, whether the patient has ever had typhoid fever or any disease simulating it before, and secondly, how many days he has been ill before applying the test. In addition to this, we must be careful to dilute the serum sufficiently, and to continue the observation for a definite and short period. This interval, known as the "reaction time" is now generally accepted as half-an-hour. If, then, a reaction is obtained with the serum of a patient in a dilution of 5% within a reaction time of half an hour, and the patient has not previously had an attack of typhoid fever, he is in all probability suffering from the disease at the time the serum is collected. If on the other hand, the serum

does not react with equal parts of serum and cultivation on or after the tenth day of illness, it is extremely improbable that the patient is suffering from typhoid fever.

That typhoid fever is a water-borne disease, and that the *materies morbi* is actually carried by drinking water is well known. The bacilli gain access to the water through the dejecta of typhoid patients, and their presence in the water will be accompanied by other evidences of sewage contamination, both chemical and bacteriological.

The detection of the typhoid bacilli in water is attended with great difficulties. This arises from several reasons. In the first place, the suspicion that the water is spreading the disease often does not arise until several cases have occurred, all of whom have been drinking the same water, and as these cases will not arise until about three weeks after the actual pollution and infection, it is quite possible that the organisms may have disappeared from the water by the time it comes to be examined. Secondly, the typhoid bacilli will never be at any time in any great numbers in the water; never in anything like such numbers as the bacillus coli communis. Thirdly, the presence of other organisms, particularly of the bacillus coli communis in the artificial media tends to the disappearance of the bacilli of typhoid fever.

In view of these facts it will be seen that, although the typhoid bacilli should always be searched for in any suspected water, the failure to find it will not be much evidence in favour of the water. Fortunately other evidence is often forthcoming which is quite sufficient to condemn it on the ground of sewage contamination.

The organism which is looked upon as a sign of sewage contamination is the bacillus coli communis. This bacillus is an organism that is found normally in the intestinal tract of man and most if not all mammals. So long as it remains localised to the intestines, it is not only harmless, but probably very useful. When, however, it leaves this position and gets outside, it may do a considerable amount of damage; it is frequently found as the cause of perityphlitic abscesses, and in abscesses in other parts of the body.

If we are fortunate enough to have isolated the bacillus typhi abdominalis from a sample of drinking water, we should, of course, condemn the water at once. If, however, as often happens, we cannot find it, the great question arises, does the presence of the bacillus coli communis render the water unfit to drink?

The points to be considered are 1st, to what extent the bacillus coli communis must be considered as evidence of sewage; 2nd, the source of the water; and 3rd, the actual number of these bacilli found.

The bacillus coli communis, as has been already said, is an organism that is normally found in the intestinal tract of the lower animals as well as man. If, therefore, any of the excreta of these gets into water, that water will contain the bacillus coli communis. As cattle frequently foul the river whose water they drink, and as dogs, rats, etc., by no means infrequently contaminate rivers, it is to be expected that the bacillus coli communis will be constantly found, even when the river does not receive any sewage effluents. In comparison with the enormous bulk of water, however, the amount of contamination from sources

other than sewage will be extremely small, and the number of bacilli per c.c. minute. When an untreated sewage effluent enters a river there is at once a very great increase in the number of organisms and in the number of this particular bacillus. As the river flows, this number rapidly diminishes on account of the nitrifying action of the bacteria derived from the soil, the action of the light and sedimentation. The river, therefore, some distance below the effluent will not contain many more organisms per c.c. than just above the effluent, and in consequence the number of coli will also have greatly diminished.

If water is drawn from a river, it should be drawn above the place where any sewage enters, and therefore above the portion of the river which contains many coli. If then this is done the water actually delivered to the consumers after effective sedimentation and filtration should contain so few coli that they can only be found with difficulty.

Sewage, instead of being turned into the nearest river, is frequently run over land, and allowed to percolate. By this means the organic matter in the sewage is got rid of by the nitrifying organisms in the soil; the organic matter and the bacteria disappear together if the soil is doing its work properly. Any excreta which is deposited on land ought therefore to be freed from coli before the water off the land reaches the drains, and the surface wells which are beneath these drains ought not to contain any coli.

From these considerations, I think we are justified in assuming that the presence of coli in drinking water is presumptive evidence of sewage contamination, because the amount of water which we can examine is, in comparison with the whole bulk of the water from the river or well, so very small.

The next point to be considered is how many coli are to be allowed in water without condemning it. About this there are, of course, different opinions. Some observers have stated that coli is present in every specimen of drinking water they have ever examined, and unless they are present in every c.c. of the water, it ought not to be condemned. Others maintain that every water containing coli ought not to be drunk.

A position between these two is probably a correct one provided that the source of the water is always taken into account.

We can consider that nearly every supply of drinking water—for large communities—is drawn from rivers or wells, superficial or deep. If the water is drawn from a river, and not filtered, we may expect to find coli, and yet not be able to prove contamination by human excreta. If it is properly filtered, about 99% of the organisms should be removed. The unfiltered water should not contain more than quite a small number of coli per c.c., let us say five as a maximum. In other words, river water containing more than this number of coli should not be used even to filter. In 100 c.c. of such a water there would be 500 coli. After removing 99% of the bacteria, there would be five coli left in the 100 c.c., i.e., one coli in 20 c.c. A sample of water containing this number, has been passed by an eminent bacteriologist as perfectly safe.

If the water is derived from a surface well or spring, the sewage and its bacteria should have been completely destroyed in its passage through the soil, and the water should be consequently free from coli. However, the soil may

crack in dry weather; drains are often constructed to carry off the sewage below the surface of the soil, and these are frequently imperfect and leak; in either case the sewage percolates through a soil, which, being below the level of the nitrifying organisms, has not the power of oxidizing the harmful constituents. In point of fact, surface wells often show evidence of such contamination, and the presence of coli in water derived from these sources is sufficient to render it suspicious in whatever numbers they may be present.

If the water be drawn from a deep well, that is, from one below the impermeable layer, the only ways in which coli can get access are: first, when there are fissures extending into and through this layer, as sometimes happens in chalk strata, and second, when the pipe is imperfect. In the case of deep wells, therefore, the presence of coli must mean the percolation of sewage, and their presence in numbers, however small, ought to condemn the water absolutely.

As cows do not suffer from typhoid fever or from any disease caused by the typhoid bacillus their milk does not contain these organisms. When the milk is the cause of an outbreak of typhoid, the contamination is always the water with which the milk has been diluted, or the cans washed. Most of my readers have been to farms, and seen the various processes of milking, scalding, etc., which take place on these farms. They have also seen the ubiquitous pump and heard of, if not seen, the almost as ubiquitous cesspool. Now this cesspool, in the ordinary course of things leaks or overflows; it ought not to, but it does. The overflow percolates through the soil below the layer containing the nitrifying organisms, and is therefore not destroyed. As the well from which the pump water is derived is nearly always in the immediate vicinity of the cesspool, the overflow of this latter has not far to travel before reaching the well water. The pump water is always used to wash out the milk cans, pails, etc., if not to dilute the milk, and therefore we can say that the cans are washed out with contaminated water.

Should one of the inmates of the farm manage to contract typhoid fever, the excreta go as usual to the cesspool, and the overflow from this, now containing the bacillus typhi trickles into the well. The vessels which are washed out with this water are necessarily contaminated when the milk is put into them. The bacilli multiply in the milk and the epidemic is started.

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PREPARING HYDROZOA FOR THE MICROSCOPE.

By George T. Harris.

THE animalcule trough of the microscopist knows no lovelier occupants than a colony of hydroid zoophytes. Fresh from the sea, their vigour unimpaired by a sojourn in the imperfectly ærated water of a temporary aquarium, each polypite emerges cautiously from its calycle and soon the trophosome bears that resemblance to a plant laden with flowers that gained for it from the naturalists of a bygone age the name of "animal-plant." What can equal the microscopical beauty of a colony of *Clytia Johnstoni* or *Campanularia flexuosa* when it has recovered from the shock of being transferred to the zoophyte trough, "and the embossed tentacles are thrown out over the margin of the little crystal dwelling, some drooping downwards, others standing almost erect (like a circle of guards) around the central proboscis." Truly it is a matter for surprise that naturalists having once seen the extreme loveliness of a living colony under the microscope should ever remain content with mounting merely the chitinous polypary without the polypites; of preserving the dwelling, lovely though it may be, without the graceful occupant.

However difficult it may have been in the past to prepare hydroids with their tentacles properly expanded, present methods of narcotisation are so perfect that the naturalist is left without an excuse for not killing his objects in an extended condition. Modern zoologists have helped themselves so liberally from the chemist's laboratory in the matter of anæsthetics that the array now placed at the command of the naturalist is distinctly embarrassing to a beginner. Each class seems to have allotted to it a particular narcotic; and almost this is so, for in practice the naturalist finds that a certain narcotic is by no means universal in its application. Hydrochlorate of cocaine, with even its general usefulness, fails signally among the Vorticellidæ; in some species acting fairly well on the ciliary wreath, in others on the contractile stalk, but with almost all forms the bells part company with the foot-stalk before narcotisation is sufficiently advanced to admit of successful killing and fixing. Even when dealing with a single class we often find the various families comprised in it demand varying treatment to get the organism fixed in a life-like form. The two primary divisions of the Hydrozoa are especially illustrative of this fact; with the various Calyptoblastic species, hydrochlorate of cocaine gives perfect results with the greatest facility, but for the Gymnoblastea it is by no means an ideal narcotic, and one is well-advised in selecting quite a different method of operation.

Among the Calyptoblastea the microscopist will find his most attractive objects, indeed the microscopist who is not also a specialist will probably pay but little attention to the Gymnoblastic forms, which, lacking the dainty calycles and variously shaped gonothecæ of their more ornate relatives, do not so readily invite the attention of the microscopist desiring simply an effective mount. Fortunately it is with the Calyptoblastic forms that success is most readily obtained, provided they are dealt with shortly after having been collected; for I myself have found when keeping them several days in small tanks that the polypites do not so

readily emerge as when recently taken from the sea, or that the polypites on one part of the trophosomé are extended while their neighbours obdurately refuse to be coaxed from the bottom of their calycles. Such a condition of affairs is rather a fortunate one for the student of this class, however, as it enables him to study the calycle rim and the extended polypite in the same mount. But the average microscopist will incline rather towards a full display of extended tentacles, and with this end in view let him select under the dissecting microscope a clean spray of suitable proportions, and clearing away adherent particles of foreign matter with a camel-hair brush, remove the selected piece to a watch-glass of filtered sea-water. In a few moments the polyps will have recovered from the rude handling and be spreading their tentacles in all directions. Have at hand a 1% solution in sea water of cocaine hydrochlorate and with a pipette add to the colony in the watch-glass about ten minims. The probable result will be an immediate retraction of all the tentacles, followed in a few moments by an effort to accustom themselves to the presence of the narcotic. Ten minutes after the first application a similar quantity may be cautiously added, which they do not seem to mind in the least, though care should be taken not to administer any shock to the colony that would be likely to cause retraction of the tentacles; for I have observed that when a semi-narcotised colony retract their tentacles they are never re-expanded satisfactorily, and nothing short of removing them to fresh sea-water will effect recovery. At the end of half-an-hour narcotisation is usually sufficient to allow of killing and fixing, for which purpose osmic acid is an ideal agent.

The strengths given in the text-books of osmic-acid solutions for killing is generally a ¼% and ½%, but in the case of Hydrozoa the strength I personally prefer is that of 1%, of which about fifteen minims should be taken in a pipette and the narcotised colony quickly deluged with it. If narcotisation has been thorough, and killing should not be attempted until the tentacles shew insensibility to the prick of a needle, the colony is now perfectly killed and fixed, though it is best to leave them in the osmic solution until a slight browning of the tentacles is apparent. When this makes its appearance the colony is washed either by removal to another watch-glass of filtered sea-water, or by withdrawing the osmic solution with a pipette and substituting plain sea-water, which is the better course. Several changes of water having been made they are ready to be "cleared." At one time I contented myself with a very thorough washing after osmic, but however carefully perfomed the mounts in time always darkened more or less; now, after using osmic I invariably clear the preparation with hydrogen peroxide or cyanide of potassium, preferably the former. It is usually recommended to mix the hydrogen peroxide with 70% methyl. spirit, but I have not found it necessary to do so, and it is certainly more convenient to leave out the spirit. The peroxide as obtained from the druggists is either a 10 or 20 vol. solution, the 10 vol. being the more convenient; one part of a 10 vol. solution and two parts of water is poured over the "fixed" hydroids and left for five or ten minutes when the brown tinge imparted by the osmic acid will have quite disappeared, and the colony be indistinguishable in form and colour from a living trophosome. A very slight washing frees sufficiently from the peroxide when the preparation is ready for mounting, or it may be stored until a more convenient time; in either case

formalin being the preservative. One part of the 40 % formalin solution diluted with sixteen parts of water being the most suitable strength.

When working away from home it is, of course, convenient to defer mounting operations until the return, simply storing the "fixed" and "cleared" hydroids in collecting tubes with the formalin solution; but where the best results are wished for there can be no doubt about the desirability of finishing the mount at one operation. The stored hydroids are almost certain to suffer in some way; particles of foreign matter dislodged from the polypary become entangled with the tentacles and require a considerable amount of care and patience to remove. All things considered, the additional time and trouble involved in mounting away from home are amply rewarded by the superior quality of the mount, and now that excavated slips are so readily and economically procured, the labour involved

Campanularia flexuosa.

is not very great. Taking a clean slip, a ring of gold size is run round the outside of the excavated cell and put aside for half-an-hour to slightly dry; the hydroid is then placed in the cell and the solution of formalin previously mentioned added with a pipette, until a slightly convex surface is formed. Usually on adding the formalin the pinnae and tentacles assume the form they had when fixed; if they fail to do so they must be carefully arranged under the mounting microscope before the cover-glass is laid on. This should be lowered carefully upon the convex surface formed by the formalin, and pressed down into contact with the partly dry gold-size, when the cell will be found completely filled and free from air-bells.

In dealing with the Gymnoblastic forms, cocaine, as previously mentioned, is not nearly so successful; in fact, personally, I have never had the least success with *Coryne* when using it. The tentacles, however cautiously the cocaine is added,

are gradually contracted until they are little more than protuberances on the coensarc. Some of my best *Coryne* mounts have been obtained by suddenly deluging the colony, placed in a watch-glass with saturated solution of picric acid. This kills them instantly before retraction of the tentacles can take place, and has the interesting effect of causing the nematocysts to discharge their filaments. So that when killed and fixed these filaments stand out rigidly all over the capitulae of the tentacles, verily "like quills upon the fretful porcupine." Unfortunately, however, it is not easy to retain them uninjured through the various processes that precede mounting. After fixing with picric acid, a prolonged washing and soaking in 70% methylated alcohol (100 vols. of methyl. alcohol and 31 vols. of water) is necessary to remove the acid, when the organism may be mounted *au naturel*, or stained and mounted in balsam. With *Clava* and *Podocoryne* I have certainly found cocaine act fairly well, but have never been able to obtain the maximum extension they assume in life unless some rapidly operating agent like sublimate was used.

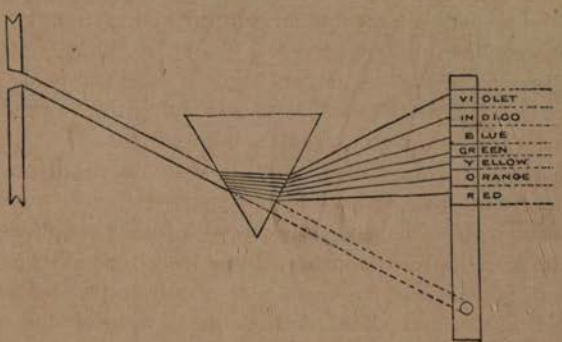
When collecting hydroids for the microscope, a large amount of labour is obviated by a judicious selection of the collecting ground. On sandy or muddy shores the littoral forms are so encrusted with mud, sand, and diatomaceous growths that it is almost impossible to obtain clean mounts. Therefore it is important to choose localities where the water is fairly free from suspended matter; nor is this so difficult as at first sight it might appear. Often in half a mile of foreshore one is able to select spots strewn with seaweed-covered boulders forming rock-pools, perfectly free from sand and silt. During the summer of 1897, when collecting on the Welsh coast, I was much dismayed at finding the polyparies of nearly all the littoral forms encrusted with sand almost beyond recognition; however, by selecting my ground a mile or so further away, I was able to obtain the same species comparatively free from extraneous growths and matter. It is a good plan to clean the trophosome before commencing to narcotise, by holding it under water with a pair of fine forceps and gently passing along it a soft camel-hair pencil; this operation, performed carefully several times in fresh waters, will materially help in obtaining clean mounts.

Such is the process that has given me perfectly satisfactory results in working among the Hydrozoa; but to avoid misconception, it is perhaps desirable to state that the method in its simplicity is one well known to biological workers. Cocaine was applied similarly by Richard so far back as 1885, osmic acid is a well-known killing and fixing agent, whilst formalin has already revolutionized modern preservative methods; hence my part is the very modest one of *raconteur*, wherein I detail the working of classical methods in my own practice.

ACHROMATICS versus APOCHROMATICS.

By Edmund J. Spitta,
M.R.C.S. (Eng.), L.R.C.P (Lond.), F.R.A.S.

IT has been said that "seeing what you know and knowing what you see" are two very different things. By this is meant that it is far easier to recognise special characteristic features in anything with which you are familiar, than to discover new details about the object for which you are neither mentally prepared nor have practised your eye to see. This is especially true with the microscope and applies very strongly in determining the relative value of lenses by different makers, but perhaps more especially so when a definite decision has to be arrived at—which gives the better image the achromatic or the apochromatic ? To the tutored eye small differences in definition, powers of resolution, blackness of shadows, flatness of field, etc., are all at once easily recognised ; but to the less experienced it becomes a tax of much greater proportions and often necessitates a regular training of the eye to thoroughly appreciate. The same remark of course applies to the comparison of photographs produced by the



different lenses—unless you know what to look for and how to look for it. It is the aim then of this article to assist those less acquainted with the subject to do this with a little practice for themselves.

Before however approaching the actual subject itself, it is necessary first to touch upon the theoretical difference which underlies the manufacture and construction of these different classes of objectives, not from a mathematical point of view, for that is not within the scope of this paper, but in what it is hoped may be considered a practical manner.

Probably every reader of this book knows full well what is meant by the word Spectrum—the rainbow effect that is produced by a beam of light passing through a prism of glass. Such an experiment most of us have been the unconscious witnesses of when we noticed the colours produced by the sun shining on one of the pendants of the glass lustres which used to often adorn old-fashioned mantelpieces. The actual path of the ray of light passing through the prism is in exaggeration, shown in the adjoining figure, which everyone must recognise who has even glanced at a textbook on light. It will be seen, first, that the

im-merging beam of white light is broken up into several *e*-merging rays which are now all of different colours; and secondly, that these emergent pencils, although their edges are continuous one with another, do not overlie each other but appear fairly well separated, the violet being the most bent, then the blue, next the green, followed by the yellow, whereas the red is the least bent of all. This difference in bending of the rays, it is well known, is entirely due to the difference in the respective wave-length of the individual colours. If we pursue our experiments a little further, we shall find that the more dense the glass becomes of which the prism is made, so much the more usually are the colours bent as well as separated out, such separation being technically known as "dispersion." But this is not all. When comparing the dispersion produced by different kinds of glass, that is, glass in the manufacture of which different minerals are used, we notice another peculiarity and it is this, that although two glasses may not perhaps differ so very largely in density, yet prisms made with them do not produce the same kind of spectra. One glass, for example, will spread out the violet end and yet bunch together the red and the yellow, whereas another will largely spread out the red and the yellow and afford but little dispersion of the colours in the violet end of the spectrum. Such peculiarity is rightly called the "irrationality of the spectrum," and the colours introduced from this cause in an image are said to result from the non-elimination of the "secondary spectrum."

Let us now consider for a moment what all this has to do with our subject? To fix our ideas we must first bear in mind that an image of the illuminant is formed by each colour, so that if the sun had illuminated the prism in our previous experiment, with suitable arrangements we should have seen an image of that luminary in each colour. Then, secondly, as a simple lens is nothing but a congeries of approximated prisms varying only in size and shape, so it is not difficult to understand that along its axis there would have been represented a consecutive series of sun-images in all the colours of the rainbow, not one of which would have lain in the same plane as any other.

In theoretical achromatism then for colour, what the optician of course would wish to do is to be able to make all these colours bring their respective images to one and the same focus on the axis of the lens, irrationality of the spectrum being for the moment disregarded. In the manufacture of achromatics however, this is an absolute impossibility, and the optician has to be content, so to speak, with combining certain colours for visual purposes to give the best resulting image—yellow or yellow-green for seeing with, and yellow and blue-violet for photographing with, leaving all the others outstanding. Prof. Abbe some years ago gave a large amount of attention to the theoretical aspect of the case and came to the same conclusion as others had done before him, that no improvement could be effected in achromatism, especially in the elimination of the secondary spectrum, until the optician was provided with new kinds of glass possessing properties at that time only dreamt of in theory. At length, however, Jena glass was introduced, which gave to the world many of the kinds of glass that had been wanted, thus creating quite a revolution in lens-making. The words "many kinds" are used, because for the present they do not seem able to make a description having the

Fig. 2.

Fig 1.

Fig. 3.

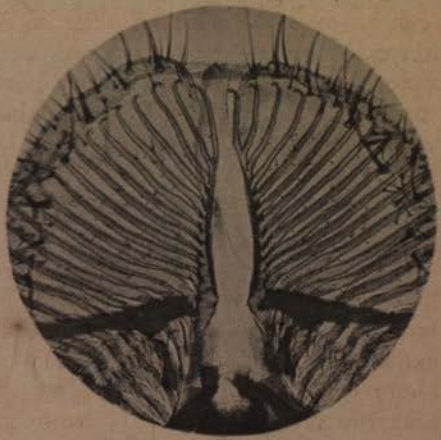


Fig. 4.

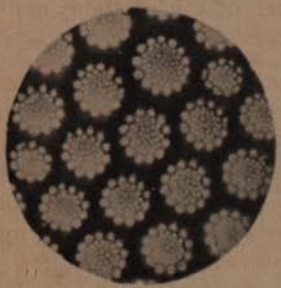


Fig. 5.

Fig. 6.

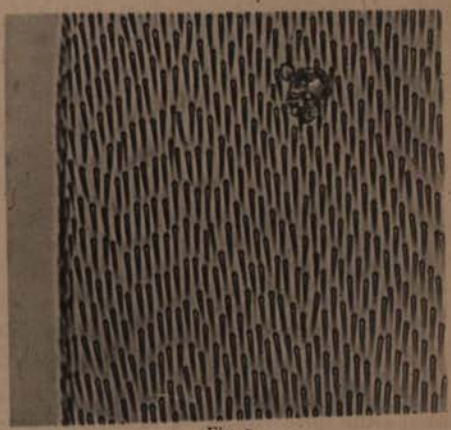


Fig. 7.

To face page 84.

same peculiar properties possessed by the mineral "fluorite" up to the present so absolutely necessary in the construction of the apochromatic. Having the new kinds of glass at command, Prof. Abbe originated his celebrated system of Apochromatism, which, he says, differs essentially from all others hitherto designed. Apochromats realize simultaneously two conditions not hitherto fulfilled by any other optical combination: (1) By the union of *three* colours in *one* point of the axis which enables the optician to eliminate the secondary spectrum; and (2) the correcting of spherical aberration for *two* different colours in contradistinction to the hitherto usual correction for *one* colour only in the brightest part of the spectrum.

To fix our ideas then, let us put the matter another way. With the achromatic the greatest sharpness of the image hitherto formed was limited to one colour, or two at the most, of the light transmitted (yellow or perhaps yellow-green for visual lenses and blue-violet for those used in photography), while all the other rays of the spectrum gave more or less confused images, appearing as coloured images (fringes surrounding the sharp image), and partly as a general haze spread over more or less the entire field. With the new system, however, the images are nearly, if not absolutely, sharp for *all* colours, hence the quality of the finite image whether visually or photographically considered *is independent entirely of any special colour of the illuminant.* It is easy therefore to understand the great value of these lenses in defining difficult structures and how it is that they give such sharp and excellent photographs, let alone such white and colourless images of objects like diatoms. Again too, Prof. Abbe pointed out that in achromatics colour correction was only obtained for *one* zone of the objective, the others being more or less defective, but that in his apochromatic system the chromatic aberration was corrected equally in *all* parts of the field. That affords a reason why the resulting definition is so fine because the image produced by each colour is said to perfectly coincide with that of the rest.

But there are yet two other points of interest which must be mentioned and they are:—(1) That owing to all these perfections mentioned so much more *light is obtained.* Dr. Dallinger has stated that an ordinary achromatic of the best type would only pass 140 parts, but an apochromatic, 225 out of a possible 300. (2) That also owing to the perfection of their performance the apochromatics permit the use of eyepieces of extraordinary power without producing what is technically known as a "rotten image." An achromatic will only permit the use of an eyepiece having at the most the initial magnification of about 4 to 6, but so perfect is the performance of the new system that it is easy to use eyepieces magnifying 8 to 10 diameters, often 18, and in special cases 27, with rare instances of even 40. The evolution of thought is so peculiar that a question is often here asked: "If this property for bearing high eyepieces be true, and certainly it is, what is the use of making high power objectives at all, seeing that so much magnification can be done at the eye-end with eyepieces? To reply to this must be our next subject. In olden days up to about the year 1874, power *per se* was all that was thought to be effective in making an object distinct, and its details plainly visible. It is not a little strange to think that up to that date there appears to have been an entire absence of knowledge, even by experts, both in theory and practice as to the real optical principles that enable one to see an image produced

by the microscopic objective. But in 1877 or thereabouts, Prof. Abbe gave to the world his great diffraction theory which has inaugurated an entirely new epoch in both the theory and construction, as well as the adaptation and use, of microscopical lenses. But before this time, however, as knowledge had grown and experience accumulated, it had become to be slowly recognised that a "something" beyond simple magnification affected the defining power of objectives, and at last it was in a great measure traced to the fact that the reason why one lens *defined* so much better than another, although of the same initial magnifying power, was due to the fact that one had a *greater aperture than the other.* Hence to increase the aperture rapidly became the aim of the optician. But here it should be distinctly stated that the aperture, or numerical angle of *the objective* must not be confounded with the still older idea that excellency of result depended on the angle of obliquity at which the light *emerged from or to the object*, involving as it did some specially assumed property of a special kind in the obliquity taken *as such*, for Prof. Abbe made a most careful and profoundly scientific enquiry into the matter, and found that there was no basis whatever for such an assertion. No, it had been formed on wrong conceptions, and wonderfully did he expose and demolish the theory in a manner too long to enter upon here in a short article of this nature. *The* angle is that formed *in the objective.* To put the matter in another way, perfect definition is wholly and absolutely dependent *not* upon the obliquity of the rays *to* the object, as before believed, but in truth upon the obliquity they bear *to the axis of the microscope.* To repeat then, to increase the *aperture* of the objective is found to be *the* means for improvement of definition. But Prof. Abbe went further into the matter and found that increased aperture seemed to admit "*a something*" more than the true dioptric image, and this "*something*" he ultimately discovered by a series of elegantly and well-contrived experiments to be nothing more or less than *the diffraction rays which proceeded from the object itself.* Pressing the subject to its logical conclusion, he found that the *more* of these rays that were admitted to the optical combination, i.e., the *greater* the numerical aperture of the objective, *the more* the similarity that would exist between the object and its image. We are now in a position to reply to our question, and the reply is simply this:—The *higher* the defining power of the objective, the *greater* is its numerical aperture (usually written thus "N.A."), and as the definition depends on the greatness of this aperture, so it directly follows the *higher* the power used the *better* the final result. Two photographs are appended, the first (fig. 8) is taken with an objective of very high N.A. and a low eyepiece; the second (fig. 9) with an objective of low N.A. with a high eyepiece to get the necessary magnification. One more remark on this portion of our subject and we will pass on. Seeing that achromatics, especially the higher power ones, cannot without great difficulty be made with such high numerical aperture as those built on the apochromatic system, so the former cannot on this ground—if on no other—be expected to give the results that the new system affords; still, on the other hand, it must not be omitted to be said that owing to the introduction of the new Jena glass, ordinary achromatics have been most wonderfully improved and some of the most recent lenses have reached a perfection hitherto thought impossible; such, for instance, as the new inch, by Ross, N.A. ·3; Leitz one-and-a-half inch, and his tenth; a new twelfth by Beck; No. 6 by Reichert, and others. This statement is of importance

to the student, but still there is no getting away from the fact that by the use of apochromatic objectives of the highest order, we verily believe all the great discoveries of the present and probably of the future will be done.

We have now to compare the performance of the achromatic and the apochromatic lenses visually and photographically.

It is presumed the reader knows the value of employing what is called "*critical light*," and how to obtain it; lest, however, such should not be the case, the following is the method of obtaining it: Critical light is said to be obtained when the *substage condenser and the objective* are both in focus on the object. This is easily done as follows:—First focus the object in the usual manner and then rack the condenser up or down until the edge of the flame of the lamp is distinctly seen in the field accurately focussed. To those unaccustomed to this class of illumination it may appear objectionable, but no lens can be said to be performing at its *best* except under these conditions. The light, if the objective be of low power, may be too intense; if so, the Iris diaphragm may be closed until the image loses its flooding of light, so long as the image does not suffer in definition, because, cutting down the light by the iris will lower the N.A. of the objective, but seeing that the low powers have much less aperture than the high ones, a certain amount of contraction of the iris will do no harm and will much improve the image. *Great care* must be exercised however, when attempting to do this with high powers, for fear as before explained, of reducing the N.A. of the objective, which of course means spoiling its definition; should the light still be too intense with low powers however, then smoked glasses or monochromatic ones should be interposed between the illuminant and the condenser.

Lastly it is important that the condenser should be suited to the objective so far as relates to its N.A. Theoretically, both should have the same aperture, but practically, no objective will stand this except perhaps when looking at or photographing bacilli: but on the other hand it is necessary in order to obtain good results not to use the condenser with *too* low a N.A.

As before stated, a small amount of cutting down by the iris is justifiable under certain conditions, and most authorities set the maximum limit at about *a third of the diameter* of the back lens of the objective, excepting when employing the microscope on bacilli. Then lastly, to obtain the best results, certainly when photographing with the microscope, an achromatic condenser is a necessity, and the use of an apochromatic one is better still. Messrs. Powell & Lealand have recently brought out an excellent dry apochromatic condenser of ·95 N.A., whose performance leaves little to be desired. It may seem as if these remarks on the condenser were uncalled for considering the nature of the subject under consideration; but attention is called to all these details as it is positively certain *no* objective will perform at its *best*, unless the greatest care be exercised in the application and suitability of the condenser and the arrangement of the light.

Before actually comparing lenses, suitable test objects should be chosen and carefully studied. The Proboscis of the blow-fly for low powers is good, but besides this a Podura Scale and some finely marked diatoms must be obtained; and lastly, if it can be possibly procured, a *really* good specimen of the Amphipleura

Pellucida mounted in realgar. The observer should make himself a master in readily obtaining "critical light," and in illumination generally, for the relative excellence of one glass over another may very largely depend on a fortunate illumination. Then too he must possess himself with an unbiassed mind, remembering to compare objectives so far as possible of similar N.A., and not to be content with a desultory off-hand examination, but rather that he should examine the performance of each lens step by step as the programme given below proceeds. He must dispossess himself too of any extravagant expectation, for this may beget a belief that certain performances ought to be present which perhaps may be even theoretically impossible with the aperture employed; and on finding them absent, such absence of the ideal may induce a strong and unconquerable feeling of disgust that adds a heavy load to be overcome before coming to an unbiassed final judgment.

Let us take now an inch achromatic and an inch apochromatic to compare their performance, using ordinary eyepieces for the former objective and compensating ones for the latter, and use the proboscis of the blow-fly as the test object. The programme suggested—although it is not intended to be exhaustive—may be conveniently arranged as follows:—

1.—Flatness of field.
2.—Blackness of shadows in the image.
3.—Brilliancy of the illumination.
4.—Resolving power.
5.—The absence or presence of colouring fringes around minute objects such as fine hairs, or the dots in diatoms.

1. Flatness of Field.—By this is meant that after focussing the centre of the object, the edges of the field, if the specimen reaches so far, are equally sharp. The antithesis of flatness of field is called roundness or curvature of field, these two terms being in this paper considered synonymous, although some writers do draw a difference between them. It will be seen that the flatness is ofttimes of larger area—reaching further to the edges in the achromatic than with the apochromatic, but that the definition in the centre is superior in the apochromatic than in the achromatic image. In some "inches" by first-class makers, such as in the new inch by Ross, ·3 N.A., and one by Leitz & Reichert, it is not easy without close attention to discern any inferiority of image to that presented by the apochromatic, for the improvement afforded by that type of lens does not become so very evident when compared usually with excellent achromatics using low eyepieces, until a little higher power is employed, although apparent in photography. But note one thing, that the curvature of the field and the consequent loss of definition at the edges presents this difference in the two cases. In the achromatic no amount of refocussing will render the periphery sharp, but with the apochromatic the slightest turn of the screw renders the edges of the field as good as the centre—hence the mind can rapidly acquire a mental picture of the *whole* image by a touch of the screw. With the achromatic, however, if the edges be required to be examined, that portion of the specimen must be brought to the centre of the field before focussing renders the definition as good as possible.

Fig. 8.

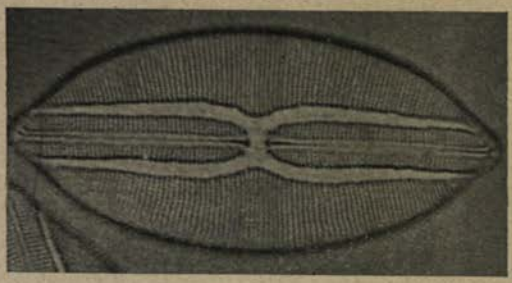


Fig. 9.

Fig. 10.

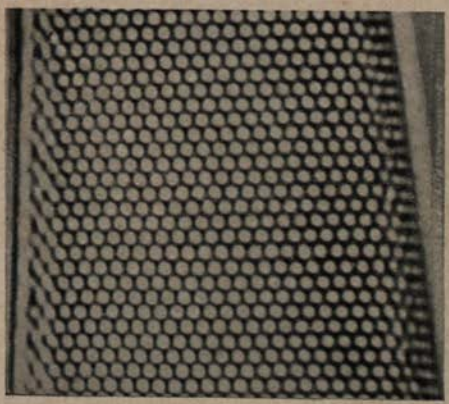


Fig. 11.

Fig. 12.

To face page 88.

2. Blackness of the Shadows or Dark Portions of the Image.—Notice whether the dark ribs, or tracheæ as they are called, of the proboscis are really black, and see which lens renders them the more so. Look carefully to see if there be a haze over the whole image like a veil which no management or adjustment of the light, condenser, or otherwise will get rid of except by sacrificing the definition of the objective by closing the iris diaphragm. The apochromatic to the practised eye will here show a superiority.

3. Brilliancy of Image.—Here a good deal of practice is necessary, as much depends on the actual illumination of the moment; but rapid change of the lenses nearly always affords a ready method of perceiving the superiority of the apochromatic.

4. Resolving Power.—This is directly proportional to the N.A. of the objective. By resolving power is meant, speaking popularly, the power possessed by the lens of breaking coarse details into still finer ones, and of rendering the fine details so distinct as to merit the term of being "picked out." The black markings of the trachea should with the inch look picked out and so sharp and clean-cut, that they ought to give the impression that they are drawn with a pen on paper. Remove now the proboscis and place on the stage a large diatom, such as an Arachnoidiscus, and notice how the fine markings are shown by each lens, and how white and colourless is the image in the apochromatic.

5. Absence of Colour Fringes.—Around and about the markings of the diatom, and between the striæ or between the dots, there will be seen a certain amount of colour fringes with the achromatic, which are entirely absent in the apochromatic owing to the elimination of the secondary spectrum. Return now the proboscis slide and look at the large hairs and note the difference in their fringe-like appendages.

The same specimens will do when comparing the images produced by two half-inches, each being of similar aperture, when it will be found the contrast in the images will be more marked. Use also a diatom with well-marked striæ such as a Navicula major. When comparing two $\frac{1}{8}$ths, a podura scale may be also employed. The light wants careful arrangement to use this test. The markings should look "punched out" and very black with a central white streak; diatoms should be tried for colour fringes, especially the Navicula. An eighth and a twelfth immersion require much more careful testing. A podura scale should show the white centre to the note of exclamation as it is called, with a narrow constriction near its broad end, and its point as a fine straight line extending some long way down in the black. Diatoms possessing the finest markings should be now resorted to comparing the quadrilateral dots in the Surirella Gemma, the hexagonal markings in the Pleurosigma Angulatum, the canaliculum in the Pleurosigma Balticum described by Dr. Van Heurck, and the small central portions of the Aulacodiscus Sturtii. To these may be added by some authorities the resolution of the close rulings in Nobert's lines. When using oblique light with a condenser of high N.A., the lines in Amphipleura Pellucida, should stand out well defined, if the specimen be well marked. In all these tests the performance of the apochromatic is unapproachable by the achromatic, especially in the case of

photography with them. It must be here remarked that all high-power objectives, according to a great authority in lens construction, can be made for special objects to give much more excellent results than those lenses corrected for general purposes, but then the objective is so restricted in its application that it necessitates others being obtained each for its special use, which involves great expense. By this is meant a lens constructed to show bacilli with a flat field may not perform so well for resolving the fine markings on diatoms; and one especially corrected to separate lines with "oblique light" may often not be such a good "all-round" lens as another which does not perform under these circumstances quite so well. This constitutes a great difficulty when comparing the performance of different lenses. When using ordinary achromatics for photography, a great falling-off in results is evident at once unless they are specially corrected for the purpose. Of late years, however, objectives have been made which give very fair results as photographers with good performance as visual lenses, and it is with these that the comparative photographs shown at the end of this article have been taken, so as to compare the best results of the achromatic with the performance of the apochromatic.

Space will not allow explaining what is meant by penetrating power, which is of course the reciprocal of the resolving power, or how the numerical aperture can be measured by the Abbe apertometer; neither can room be found to show how definition may be affected by bad centring of the lenses by which is meant the irregularity of the alignment in the optic axes, the parallelism of their planes or in the setting of their planes at right angles to the optic axis: neither can the reader be afforded information upon the effects produced in the performance of a lens by using a solid cone of light from the condenser or a hollow one; axial illumination or the other form to which the term "oblique light" is usually applied, these remarks are somewhat foreign to the comparison of achromatics with apochromatics, and would more properly be found in a brochure on lens testing, or in a textbook on the microscope.

EXPLANATION OF FIGURES.

Figs. 1 and 2 are paired group of diatoms. Fig. 1 being photographed with the apochromatic 1 in.; Fig. 2 with a 1½ in. achromatic. It will be seen on comparison that the fine markings on many of the diatoms are better shown in the former than in the latter photograph.

Figs. 3 and 4 are photographs of the *Proboscis of the Blow-Fly*, taken respectively with a 1 in. apochromatic and an excellent 1 in. achromatic. The superiority of the resulting image is apparent. The tracheæ were focussed in each case.

Figs. 5 and 6 are photos of the secondary markings in *Coscinodiscus Asteromphalus*. Fig. 5 being taken with an apochromatic 3 mm. N.A. 1·40, Powell & Lealand's

apochromatic dry condenser, F line screen. Fig. 6 with an excellent achromatic 2·5 mm. N.A. 1·30, also with the F line screen, and a Zeiss achromatic condenser. Compare the refinement of detail in fig. 5 (apo.) which is slightly more magnified.

Fig. 7. Photograph of *Podura Scale.* 3 mm. N.A. 1·40 apochromatic Powell and Lealand's apochromatic dry condenser, N.A. ·95. This is to show the perfection of chromatic correction which only apochromatics display. Taken with white light the photo shows the notes of exclamation minutely defined. The constriction about the head and the prolongation of the white streak are well shown if examined with a magnifying glass. Achromatic objectives show so much colour that these minute details are in a photo blurred and lost owing to the non-elimination of the secondary spectrum.

Figs. 8 and 9 are both photos of *Navicula lyra* with apochromatic objectives. In Fig. 8 an objective of high N.A. with a low eyepiece was utilized. In fig. 9 an objective of low N.A. and high eyepiece. These show how resolving power is directly due to the N.A.

Fig. 10. *Amphipleura Pellucida.* ×2300 diameters. 3 mm. apochromatic N.A. 1·40, eyepiece 27. Powell & Lealand apochromatic dry condenser, N.A. ·95. Taken direct with F line screen and oblique light from a specimen prepared in realgar. The lines are 76,000th of an inch apart. If an ordinary hair of the head be longitudinally divided into 400 slices, one of these slices would approximately lie between two of these lines. At this magnification it is almost, if not absolutely impossible to photograph these lines direct with an achromatic, as they will not stand sufficient eyepiecing.

Fig. 11. *Pleurosigma Angulatum.* ×2700 diameter. 3 mm. apochromatic, N.A. 1·40, eyepiece 18. Powell & Lealand apochromatic dry condenser. Focussed on the upper surface of the valve and subsequently enlarged.

Fig. 12. *Surirella Gemma.* In realgar, ×2000 diameters. Photographed direct to show the striæ resolved into dots. Taken with 3 mm. apochromatic, N.A. 1·40, eyepiece 27. Powell's apochromatic dry condenser.

A PLEA FOR THE STUDY OF THE MICRO-FUNGI.

Greenwood Pim, M.A.

THE domain of natural science is now so vast that no one person can deal in any detail with more than a small section or sub-section if he wish to do any serious work, and not to be merely a scientific butterfly, flitting about from one thing to another. Hence it follows that specialisation becomes inevitable, and this is as true in microscopical science as in any other department, and the possessor of a microscope must choose the subject at which he desires to work, and stick to it; but he must, of course, acquire sufficient knowledge of the immediately kindred subjects to be able readily to distinguish his own specialities from those which most nearly approach them.

To those whose taste lies in the direction of botanical rather than zoological investigation, and who may be in doubt as to what group to take up, I would submit the claims of the smaller Fungi—those which in general require the microscope for their determination, as contrasted with the larger forms which are readily recognised by the naked eye or hand lens, and which only need the higher powers for the elucidation of their minute anatomy, as in the phanerogams and higher cryptogams These microscopic fungi present many points of advantage over their larger brethren. They are extremely varied in structure, but some of them are to be found almost everywhere where organic substances exist: on living leaves; on dead branches, twigs, leaves and stumps; on jam and paste; on old shoes; on chemical solutions; some even on living, but unhealthy fish (salmon disease) and on insects. In general, they are easily preserved as herbarium specimens, and in mounting for the microscope need but little exceptional apparatus or skill in manipulation. Many are exceedingly beautiful, being surpassed in this respect by few, if any, other microscopic objects. Again, although England and Scotland have been fairly explored by hunters of both macro and micro-fungi, I think few will assert that these countries are by any means exhausted; while, with the exception of two or three small districts, Ireland is a *terra incognita*, and I think a good deal still remains to be done in Wales. Hence there exists among these lowly plants a far better chance of coming across forms new to the British Flora, or even to science, than is the case with other divisions of the vegetable kingdom, such as mosses, algæ, liverworts, etc.; and only those who have experienced it know the pleasure of discovering even a humble mould which has not been hitherto recorded.

Given a fairly good microscope with 1 inch and ¼ inch objectives or their equivalents, the remaining necessaries are the usual glass slips and covers, a scalpel, a razor, a forceps, a few needles and a bottle of Dean's medium. In very many cases it is sufficient to pick off a small portion, say of a pustule of Puccinia, place in a drop of water, put on the cover glass and flatten out, moving the glass to separate the spores, when the main characteristics will be easily made out. To get an idea of the entire structure, and its relation to the nidus on which it is growing, a section of the leaf should be made. This can readily be

done by placing the leaf in a slit piece of elder pith, and cutting both leaf and pith with a sharp razor. With a little practice it will be found that fairly thin sections can be made without much difficulty. The asci and sporidia of the Sphæriacei may be obtained by crushing the conceptacles under the cover glass. Moulds of the Aspergillus nature are not so easily dealt with. Their spores are attached very loosely, and the whole character is dependent on the attachment and grouping of these. Hence, if placed directly in water the spores would be washed away, and the specimen become valueless. This difficulty can be overcome in a great measure by placing the piece intended for examination on the glass slip dry, adding a drop of absolute alcohol or acetic acid, and then a drop of Dean's medium. If glycerine jelly be used, the alcohol sometimes precipitates the gelatine in a cloudy form, but with Dean's medium there is less trouble, and the alcohol gets rid of air bubbles, which are otherwise very annoying. In specimens mounted without alcohol, bubbles can be got rid of by boiling gently over a spirit lamp, but this cannot be done with moulds. When the specimen is not wanted permanently, a mixture of glycerine and water makes a good temporary mountant; in this it will remain for a long time without drying up.

I now propose to give a very brief outline of a few of the principal groups of Micro-fungi.

Uredineæ and Ustilagineæ.—These are the Rusts, Brands and Smuts which are found on corn and many other plants. They are true parasites, occurring on living leaves, and are characterized by a great development of spores in proportion to the vegetative portion or mycelium, and were formerly called Coniomycetes, or Dust-fungi, for this reason. As examples, we may take Phragmidium bulbosum (rubi), which is exceedingly common on the bramble in summer and autumn, and forms little sooty patches on the under side of the leaf. Under the microscope it is seen to consist of oblong bodies divided into four or five sections, and having a kind of handle at one end; these are the "teleutospores." Mixed with the teleutospores will probably be some globose warted yellow bodies, formerly placed in a separate genus (Lecythea), but now known to be only another stage of the Phragmidium, and called uredo- (or brand) spores. Other species occur on roses—often doing them much injury—on raspberry, barren strawberry, etc.

In the closely-allied genus, Puccinia, which forms the rust of wheat, and of which other species are found on a great variety of wild and cultivated plants, the teleutospore has only two compartments, and in addition to the uredo-spores which occur on the same plant as the teleutospores—usually earlier in the season—a third form of fructification is met with in many cases, which is so unlike the Puccinia that it was placed in a separate order and genus, called *Æcidium*, popularly *Cluster Cups*. These are generally found on entirely different kinds of plants from the Puccinia, and form groups of tiny cups, usually yellow or white, with fringed margins and yellow spores within. They are now described as the "æcidiospores" of the Puccinia. One of the commonest is that found on leaves and fruits of the gooseberry; in the former the leaf is red above, and the cluster of cups beneath yellow, forming a very pretty low-power object for the microscope.

We have thus a most remarkable alternation of generations, for the spores of the berberry Æcidium if sown on wheat plants will give rise to the wheat Puccinia, and the teleutospore of the latter will produce the berberry Æcidium. This has been proved by numerous experiments by Plowright, De Bary, and others, not only in the case of the wheat Puccinia, but in many other species.

Various species of Puccinia may be met with on violets, grasses, plums, beans, willow-herb, primroses, thistles, ground ivy, box, periwinkle, and very many other plants. Æcidium forms occur on colt's-foot, primrose, anemone, berberry willow-herb, buttercup, dandelion, nettle, etc.

The Smuts, Ustilagineæ, are usually intensely black and very generally occur in the floral organs, stamens, ovary, seed, etc., while the Uredineæ are mostly brown and yellow, and chiefly affect the leaves and stems of the host plants. The best-known example—Smut of oats—may be found in almost every cornfield in autumn, the parasite converting the ear into a shrivelled mass of sooty powder. The conidia or spores are exceedingly numerous and very small. Another common, but easily overlooked species is the Bunt of wheat. This is entirely enclosed within the ear, and is not seen till the seed is crushed which, instead of affording white flour, gives only a blackish evil-smelling dust. Its conidia are much larger than in the smut of oats, and delicately spinulose. They give rise on germination to curious secondary spores. Other smuts are met with on the goats-beard, scilla, carices, scabious, silene, stems of buttercups, etc.

Perisporiacei.—This is another group of true parasites of which the Mildew of the vine and of the rose are the best known, if not very typical examples, inasmuch as their fructification is rarely seen. In their earlier stages most of the species produce a white bloom on various leaves, consisting of a well-developed mycelium, from which arise jointed threads; these readily break apart at the joints, and are capable of reproducing the plant; the vine and rose mildews seldom get beyond this stage. In other cases, however, spherical bodies, called conceptacles, are found amongst the mycelium; these usually have appendages which are very various in form; they also contain asci, or sacs, each ascus enclosing the spores. The appendages are often very curious and beautiful. In the mildew of the garden pea they are long flexuous threads. In Phyllactinia guttata, found on the hazel, ash, etc., they are needle-shaped with a bulbous base. In the mildew of the sycamore and maple (uncinula), they are divided at the extremity and recurved, resembling the sign for the constellation Aries in astronomy; in that of the poplar and willow they are curved into a spiral. Microsphæria grossulariæ, common on gooseberry leaves, has the appendages divided dichotomously at the tips and so on. The mouldy appearance is readily visible to the naked eye, and the conceptacles, if present, can be seen with a pocket lens. In mounting, one or two should be crushed so that the number of asci in the conceptacles, and the number of spores in each ascus can be ascertained. A fragment of the leaf, with conceptacles in situ, makes a pretty opaque object, while some must be detached and examined by transmitted light and a somewhat higher power to make out the details as to appendages, etc. A few forms referred to this group are saprophytes, growing on dead straw, paper, etc.

In the *Peronosporeæ* we have a third and very different group of parasitic fungi, although somewhat resembling those described in the last section. Like them the mycelium forms a delicate bloom on the leaves, usually on the underside, but it also ramifies extensively in the parenchymatous tissue, the fertile hyphæ finding their way out through the stomata. They then usually become somewhat branched, each branchlet bearing at its tip a simple ovoid or rounded conidium. This conidium readily falls off, and in a drop of water the contents become divided into about eight zoospores, which escape and swim freely by means of their cilia. Soon they come to rest, and if in a suitable nidus, such as the leaf of the plant they prey on, germinate and insert a hypha-tube through a stoma; this ramifies through the tissue and very soon reaches maturity. Thus in moist weather the plant is reproduced with great rapidity. The two best-known examples of this group are the potato disease Phytophthora infestans, and the white rust of cabbages and other crucifers, Cystopus candidus, but other species are commonly found on lettuces, onions, various umbelliferæ, clover, etc. In many instances a resting-spore is formed in autumn in the decaying leaves and stems. This develops a hard, sometimes rugose, coat, and in this stage remains over the winter, and as the weather becomes warmer, germinates and restarts the cycle. Resting-spores are found in many species of Peronospora, but so far are unknown in the potato blight.

The "damping off" of seedlings so well known to gardeners is due to various species of Pythium, which belongs to a neighbouring group. If some cress seed be sowed very thickly in a pot, some of the young plants will soon be found to bend over and often break off. If one of these weaklings be placed in a drop of water, a crop of Pythium will soon be developed.

Somewhat allied to these are the curious Saprolegniæ, which are usually found on animals, insects, etc., in water, one species causing the well-known "salmon disease." In these we have two forms of fructification, zoosporangia, which give rise to swarm-spores, and oosporangia, containing oospores, which are fertilized by spermatozoids produced in antheridia, which are branchlets specialised for the purpose.

In the black and white moulds, found on all kinds of decaying substances, we have a very great variety of forms, formerly, and to some extent still, classified under the order Hyphomycetes, in allusion to the great development of their hyphæ or thread-like vegetative system, and with them were ranged in older works most of the Peronosporeæ. Many of the Hyphomycetes are now known to be forms in the life-cycle of higher fungi of the ascomycetous order, but for those whose development has not been as yet certainly traced out it is still a convenient resting place. The black moulds or Dematiei occur mostly on dead wood and stems; the white moulds (Mucedines) on almost every conceivable organic substance, such as leaves, herbaceous stems, jam, fruit, bread, paste, leather, etc. In both series we usually find an abundant mycelium, light or dark coloured as the case may be, from which arise the fertile hyphæ, bearing the conidia, as this type of spore is commonly called. The manner in which these conidia are arranged largely determines the genus and species of the individual under consideration. Thus we may have them in tassels as in Penicillium (blue moulds)

when the hypha divides somewhat palmately prior to the formation of the conidia, and also in Aspergillus when the hypha ends in a swollen portion which bears the conidia. They are borne on irregular branches in Botrytis and Polyactis; in tufts arranged in a racemose fashion in Botryo sporium, a beautiful snow-white mould, common on decaying herbaceous stems. In all these they are more or less globose and unilocular, but they are pear-shaped and septate in Dactylium, very long and with many transverse septa in Helminthosporium, while in Macrosporium they are septate both longitudinally and transversely, giving rise to the structure known as "muricate." In fact, the variations are almost endless, and it is very difficult to convey an accurate idea of their structure by words without figures.

Another group, also popularly called moulds and which grow in similar situations, and often on dung, are the Mucorini. A pot of jam or paste is thickly studded with apparently very long slender pins, each with a small round head. This is Mucor mucedo. The round head is found to be a sporangium or capsule filled with spores, which readily germinate in a suitable medium, and give rise to an abundant mycelium which again produces the sporangia in a very short space of time. But under certain circumstances we may find a very different form of reproduction, similar to what is found in many algæ, and called zygospores. They originate thus: two neighbouring branches of the hyphæ approach each other tip to tip, become swollen or club-shaped; a septum is formed cutting off the terminal portion of each. The portion so cut off is called a *gamete*. The two gametes are at first separated by their respective cell-walls, these soon disappear and one large cell is left suspended from the two original branches. The wall quickly thickens and assumes variously warted or spiny appearance externally and has the property of retaining its power of germination for a long time. Through the genera Pythium and Saprolegnia already referred to the Mucorini approach more or less closely the Peronosporeæ.

Space will admit of notice of but two more sections of microscopic fungi—the Phacidiacei and the Sphaeriacei. Both these occur in general on dead leaves, stems, or wood, while a few are parasitic on living plants, on grasses or living insects, which latter, however, they ultimately kill. All have spores borne in asci and contained in perithecia or receptacles very like those in the Perisporiacei.

In the Phacidiacei the perithecium opens by valvular teeth, in the Sphaeriacei by a central pore; of the former a familiar instance may be found in the Rhytisma acerinum which forms black patches so common on sycamore leaves, the fruit being perfected in spring, as the leaves lie decaying on the ground. Others, such as Stegia ilicis and Trochila lauro-cerasi, are to be found on almost every dead holly or laurel leaf.

In the Sphaeriacei the conceptacles may be quite naked, as in many species of Sphaeria, or more or less immersed in a stroma or bed, which may be incrusting the branch as in Diatrype; formed into masses of various shapes as in Xylaria (the candle-snuff fungus), Hypoxylon, and other genera. In Nectria, one species of which is exceedingly common on dead stems of currant, etc., the perithecia are usually clustered together and of a rich red colour, resembling under a low power a basket of strawberries. The spores, too, are very various; some are simple,

hyaline, and shortly ovate or rounded, others of various degrees of length, and one- or many-septate, and coloured; some drawn out into veritable needles.

Some of the Hyphomycetes, as already mentioned, are known to be conidial fruit of certain ascigerous fungi; a third form of fructification is met with in the form of minute perithecia containing naked spores, formerly grouped under Sphaeropsidei; in a fourth, long glutinous tendrils, consisting of myriads of simple spores are met with, while in some cases—Sphaeria herbarum, for instance—no fewer than five forms, once considered distinct genera and species, are now united as different stages in its cycle of existence.

Thus it will be seen that there is a great field open to the investigator in working out the life history of these organisms, which, though lowly and seemingly insignificant, are in many instances of great economic importance from the injuries they cause to valuable crops and trees. Such are the potato-blight, wheat-rust, vine-mildew and many more.

As to books of reference, to the beginner, Dr. Cooke's "Microscopic Fungi" (Rust, Smut, Mildew and Mould) will be found of great assistance. The earlier editions were written when the relations between Puccinia and Æcidium, Peronospora and Cystopus, etc., were scarcely known, but probably the later editions have been brought up to date. For the Uredineæ and Ustilagineæ the student may consult "Dr. Plowright's Monograph," and for most of the other groups—except the last two, on which I know no modern work in English—Mr. Massee's "British Fungus Flora." With reference to plants injurious to trees and crops, we have Mr. W. G. Smith's "Diseases of Field and Garden Crops," and especially the English edition of Tubeuf's "Diseases of Plants induced by Cryptogamic Parasites."

In conclusion, I wish to say that the groups have not been dealt with in any sort of systematic order. They have been taken rather in a kind of biological sequence, according to the nature of the substances on which they live. I have used the word Spore throughout as indicating the reproductive body, no matter how it has been formed—whether naked, in asci and so forth. Within the limits of such an article as this it has been impossible to touch more than the extreme fringe of the subject, which to treat in detail would occupy not one but several large volumes. My leading idea has been to stimulate persons desirous of doing some microscopic work, and in doubt as to what branch to choose, to select this most fascinating study, and to leave them, not satiated, but rather like Oliver Twist, "asking for more" information.

LIBRARY OF THE BOMBAY BRANCH OF THE ROYAL ASIATIC SOCIETY

ON THE EXHIBITION OF LIVE ANIMALS AT SOIREES.

Marcus Hartog, D.Sc., M.A.

THE exhibition of Polyzoa, Hydrozoa, Rotifers, Crustacea, etc., has always been a matter of difficulty, and the following details of a method which avoids the constant need of watching to prevent evaporation, etc., may be found of interest. The animals are mounted in a hanging drop of water on the under side of the cover glass, luted on to a cell of paraffined millboard. In this condition I have preserved Lophopus and other Polyzoa for forty-eight hours, including two nights' exhibition. The following details may be found useful.

The cell is composed of a piece of millboard about $2'' \times 1\frac{1}{4}''$; in this a circular hole, $\frac{5}{8}'' - \frac{3}{4}''$ in diameter, is punched by a wad-punch, as sold by the gunsmiths. The cell is then immersed in a bath of melted paraffin candle, so long as bubbles rise; it is then placed on a glass slide, about $4'' \times 2''$, and left to cool; the side of the cell which bears the burr from the punch must, of course, be uppermost, or else it will not lie flat and stick to the slide; a number of these may be prepared at the same time, as they keep for years, and travel very well. When the time comes the cover-glass is laid on a flat surface, and the weed bearing the objects is placed on it; a needle may be used to arrange, if necessary; or the drop of water containing swimming organisms is gently put on it with a pipette. The margin of the cover must be then wiped with a corner of the handkerchief or a piece of thick blotting-paper, by a succession of circular movements, each over a short segment of the circumference; it is then left for a little till the moisture dries off from the wiped edge, and it appears quite clean and shiny; then, if necessary, a little more water may be added in the centre with a dropping-tube, a fine pipette, or even a pair of fine forceps. The cover is next pushed to overhang the edge of the flat surface on which it has been lying, taken up with the fine forceps (which must be *quite dry*), and dexterously turned over and lowered on to the prepared cell so that the drop is well over the centre of the hole. The edge of the cover must then be luted on; the instrument I use is a coarse hairpin twisted into a ring near one end, produced beyond the turn for half an inch, and bent at a right angle, the ring serving as a reservoir of heat. With this it is easy to melt shreds of paraffin so as to seal the cover to the cell, both fast and hermetically. It is best to seal at two opposite points first, so as to fix the cover at once and then fill up the intervals. Objectives up to the Zeiss D (low angle $\frac{1}{6}''$) are available.

Besides the other advantages of this system, we may note that the animals are evidently much more at home in this prison than in any of the ordinary devices. The shyest tubicolous Rotifers and Polyzoa come forth readily, stay well exposed, stand a good deal of motion without shrinking back, and when they do withdraw return into view with the least possible delay; and free swimming animals may be so confined by limiting the size of the drop as to keep them in the field under relatively high magnification. I am free to admit that the method is more troublesome than putting between two pieces of glass, a thick one and a thin one, but with the paraffin cell, once done, all is secure for the evening, the only possible dangers being those that all microscopic mounts are liable to.

THE ELEMENTARY THEORY OF THE MICROSCOPE.

By Conrad Beck.

I DO not propose in this paper, to attempt to enter into the more difficult and abstruse problems connected with the theory of the microscope. The manufacture of a microscope is complicated, and even by the light of theoretical text-books, its optical construction appears too difficult for the ordinary microscopist. It is, however, my object to show that the explanation of many of its properties is far from difficult, if it be studied by a rational method.

The theory which I am about to apply to microscopic problems is that of Gauss. This theory has within the last few years been tardily acknowledged by a few English writers; a *resumé*, or reproduction of Gauss' beautiful mathematical exposition has even been given, but it has not yet been developed in this country in such a manner as to be of practical use to practical men.

By means of the Gauss system; the elementary theory of lenses and combinations of lenses, however complicated, is rendered entirely simple, and moreover, the theory is rigidly correct within certain limits. It is true that it is only correct for that portion of the light which passes through the centre of the lens, but it is the duty of the optician to so correct his microscopical lenses, that the light passing through their marginal portions shall behave in an approximately similar manner to that passing through their centres. Thus the principles of well-made microscopes may be explained, without sensible error, by confining our attention to the action of the central light alone. It is also true that this theory is not applicable to very oblique pencils of light; the microscope is, however, an instrument in which a comparatively small field of view is made use of, while of that field it is only the central portion which is of much importance, and the *centre* of the field of view is not formed by oblique pencils.

The Gauss theory, satisfactorily explains what English text-books fail to do, and what must be explained before one can grasp the action of an optical instrument; namely, the effect of thickness on lenses, and of intervals between lenses, however complicated their form and arrangement.

At the risk of repeating "what every schoolboy knows," it will be necessary to refer to some of the well-known properties of light. At one time it was supposed that objects were rendered visible by means of some emanation from our eyes. That, as with our fingers we could touch, so, with some external invisible tentacles from our eyes, we could see. It was not firmly established till the eleventh century that the visibility of objects must be due to something emitted by the object itself, and not by the eye. That something, which renders external objects visible, is termed light, and is now understood to be a form of vibration. It moves at such an inconceivably rapid rate that in one minute it would cover more ground than could be travelled over by an express train running at full speed for twenty years.

Bodies, as regards light, are divided into two classes:—*Luminous*, those which emit light; and *Non-Luminous*, those which only reflect or scatter the light which falls upon them. The words reflected and scattered do not mean the same thing.

A body with a smooth polished surface like mercury, will *reflect* a beam of light which falls upon it in one particular direction, dependent only upon the angle at which such light meets the surface; while an unpolished surface like that of white paper, will *scatter* any light that may fall upon it in all directions.

It has been proved by experiments which need not be here described, that except under certain unusual conditions light travels in straight lines.

The light emitted by a luminous object such as a candle, travels in straight lines away from its source in all directions as fast as it is, so to say, manufactured. If this light meets with an obstacle, one portion of it is *scattered* in every direction; another is *reflected*, according to the laws of reflection; a third is extinguished, or *absorbed* by the obstacle; while a fourth part passes through the body, provided it be transparent, and is said to be *transmitted*. In this latter case the transmitted light is in general bent or *refracted*.

The refraction of light in its passage through glass is the principle which is made use of in the construction of the microscope.

A further property of light which has been established by experiment is, that each individual portion is independent of the rest and may be treated separately. If a row of trained soldiers be marched against an enemy, and some of the row be shot, the remainder will be able to proceed as before; whereas, if the soldiers had been chained together like a gang of convicts, disabling one would have interfered with the progress of the remainder. Light corresponds to the row of trained soldiers, one set of laws controls the whole, but the action of one separate unit is not affected by that of its neighbours. Thus any one of the straight line elements of light given out by a luminous source may be selected, and its behaviour under particular conditions may be investigated. Such a straight line of light is called a *ray* of light; a small bundle of rays is called a *pencil*; and the centre ray of such a bundle is called the *axis* of the pencil.

A pencil of light may be convergent, parallel or divergent.

A *Convergent* pencil is one in which the rays of which it is composed are coming towards or focussing *to* a point.

A *Parallel* pencil is one whose rays are parallel to each other.

A *Divergent* pencil is one whose rays are proceeding *from* or emerging from a point.

Light diverges from a candle. A pencil of sunlight diverges from the sun, but the point of divergence is so far away that we have no means of detecting that it is not a parallel pencil. Converging pencils are seldom met with in nature, but the burning glass converges a parallel bundle of light from the sun to the focus or burning point.

A ray of light which falls upon an object is said to be incident upon it, and is called an *Incident* ray; while one that passes from one material or medium into another is termed an *Emergent* ray.

As we have pointed out, we shall for the purpose of this investigation only have to consider transmitted light, and further we shall only deal with materials which are transparent, such as air and glass, and which are also homogeneous, that is to say, of equal density and transparency throughout.

Light will probably penetrate any known substance, provided a thin enough layer be used; on the other hand, even such a transparent material as glass offers considerable resistance to its free passage and retards it, thereby reducing its velocity.

A ray of light which is incident upon a piece of flat glass in a direction exactly at right angles to its surface, will pass into the substance of the glass without change in its direction, but with a reduced velocity. If, however, the incident ray strikes the surface of the glass at an oblique angle, it is not only

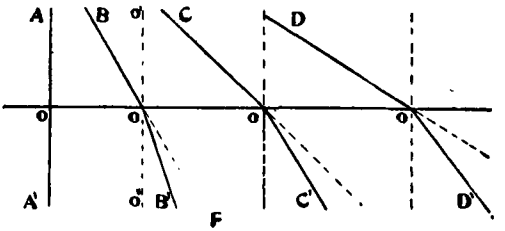


Fig. 1.

retarded, but as a result of this retardation its direction is changed, and it is bent or *refracted.*

For the present it will only be necessary to note that the incident oblique rays (B C D, fig. 1) going from air into glass, i.e., from the lighter into the denser medium, are always bent towards the line at right angles to (or normal to) the surface of the glass; and that whereas the ray A A exactly at right angles to the surface, is not changed in direction, the more oblique the *incident* ray becomes, the greater the emergent ray *deviates* from its original direction.

If the light passes from glass into air, that is to say from the denser into the lighter medium, we find that exactly the reverse action takes place. Fig. 1

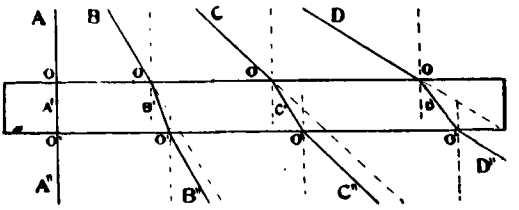


Fig. 2.

need only be turned upside down to represent it, and we might consider the the rays as coming from A' B' C' D' out of glass into air towards A B C D. Let us now examine what takes place in the case of a parallel plate of glass.

The ray A A' A," fig. 2, passes through both surfaces without alteration. The ray B is bent at the point O, into a direction O O,' meeting the second surface at some point O'; here it is again bent upon emerging into the air, and, due to the fact that the two surfaces of the plate of glass are parallel, it meets the second surface at the same angle at O' as it left the first surface at O. It is

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obvious, therefore, that it must be bent to exactly the same extent as was the case when it entered the glass, but in an opposite direction; consequently the emergent ray O′ B″ is parallel to the incident ray B O; and the light in passing through a parallel plate of glass, has suffered no alteration in its direction, but has merely been displaced laterally. The same reasoning applies to the more oblique rays C and D, but it will be observed that owing to their greater obliquity, they are displaced to a greater extent.

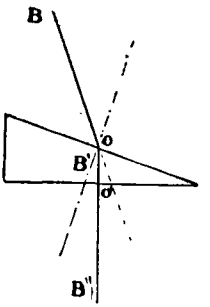

Fig. 3.

Suppose, however, that the two surfaces of the glass had not been parallel as in fig 3. The ray B, after the first refraction, does not now meet the second surface at the same angle at the point O,′ as it left the first surface at the point O, and is therefore not bent upon emergence into air at the second surface, in a manner to compensate its original refraction. In fact, in the particular case shown in fig. 3, the ray O O′ being at right angles to the second surface, passes directly through it without alteration. Thus the ray B after having passed through both surfaces of glass, is deviated from its original direction. A plate of glass in which the surfaces are inclined to each other is called a prism. A prism deflects light as illustrated above, and always in a direction away from its apex, or towards its base.

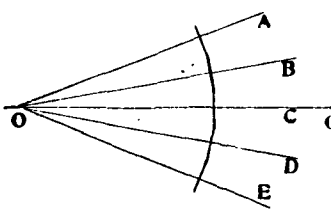

Fig. 4.

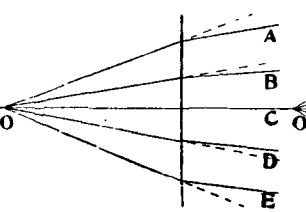

Fig. 5.

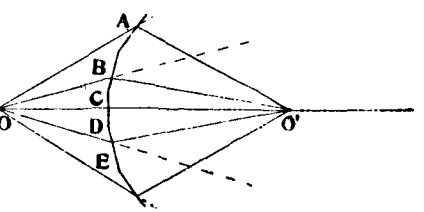

Fig 6.

Let us now consider light coming from the point O, fig. 4, in one medium, say air, and entering a denser medium such as glass.

If as in fig 4, the shape of the glass surface be such that each of the rays of light O A, O B, O C, O D, O E, meets a facet exactly at right angles to its direction, they will all pass into the glass without refraction; and if the surface of the glass be made with a sufficient number of little facets of the right shape,

every intermediate ray of light; as for instance those between the rays O A and O B, will also enter without deviation. The whole body of the light from O will pass on in the same course exactly as if there had been no glass surface intervening. This condition will obviously be satisfied when the shape of the glass is spherical—having the point O as its centre. If, as in fig. 5, the glass surface be flat, every ray except the centre one or axis will be bent or refracted; the outer rays O A, O E, being more bent than the inner ones, due to the fact that they meet the surface more obliquely. The total result of such a flat surface upon the body of light coming from point O, will be to render it less divergent, turning it inwards towards the axis. But suppose, as in fig. 6, we arrange our facets in such a manner that instead of destroying refraction as in fig. 4, we increase it. It will then be possible to so place each facet that every ray of light proceeding from the point O, will be refracted or bent to such an extent, that they will all converge to another point upon the axis at O.' When the surface is composed of a sufficient number of facets to refract all the rays to this point, this surface will have become a curve. Instead of using one curved surface to converge the light to a point O' in glass which diverges from the point O in air, a plate of glass may be used with two curved surfaces.

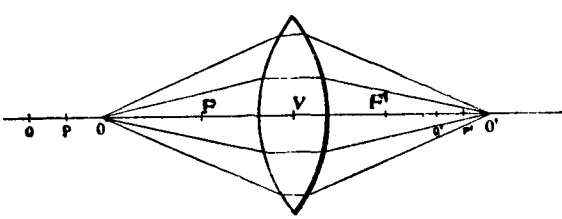

Fig. 7.

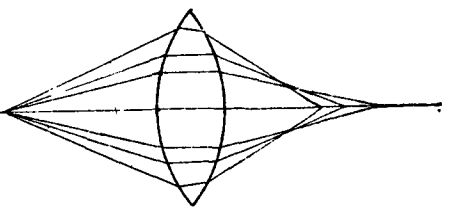

Fig. 8.

These surfaces may have their shapes so arranged that each curve will do a portion of the refraction or bending as in fig. 7; this constitutes a simple lens. One of the problems which is set to all opticians is to so construct a lens or series of lenses, that all the light emerging from one point as O, fig 7, and entering the lens, shall be brought exactly to another point on leaving it, O', fig. 7. It might appear at first sight to be merely a question of making the two sides of our lens of the required curves, but unfortunately the only curves that the optician can make with accuracy are portions of spheres; and spherical curves are not the curves required. Hyperbolic, parabolic, or elliptical curves are necessary. A lens with spherical curves bends or refracts the rays that pass through its margins more than those which pass through its centre as shown in fig. 8. This error is called *spherical aberration.* We shall not consider it further, because the optician, by means of properly arranged lenses of different shapes, can so nearly correct this error, that we may examine our microscope by confining ourselves to the rays passing through its centre, feeling confident that the marginal portions will behave as if such a thing as spherical aberration did not exist.

Properties of Lenses.—If light from a point O (fig. 7) pass through a lens, and is brought accurately to another point O', these two points, O and O', are said to be *conjugate foci*, the point O' being the conjugate focus of the point

O, and in like manner, if the direction of the light were reversed, the point O would be the conjugate focus of the point O'. Now if the point O be moved back to the point P, the position of its conjugate focus will be altered to P'; if it be moved to Q the position of its conjugate focus will be moved to Q'; and if it be moved off to an infinite distance, as for instance to the sun, the conjugate point will be at F', which is called the principal focus, or focus of the lens. Thus F' is the conjugate focus for a point which is situated at infinite distance, or, to express it differently, it is the focus of the lens for parallel light.

The position of the conjugate foci of a lens follows a very simple rule, which is algebraically expressed as follows :—

$$\frac{1}{x^1} - \frac{1}{x} = \frac{1}{\phi}$$

Where x represents the distance V O of the original point from the lens: x^1 the distance V O^1 of its conjugate focus; and ϕ the distance V F' of the principal focus from the lens. It should be understood, however, that the letters x^1, x and ϕ represent not only a distance expressed by a number, but also a direction represented by a sign + or −. That is to say, with reference to Fig. 7, we must remember that the point that is assumed to be fixed and known, is the position of our lens represented in this case, where we neglect its thickness by the centre point V, and this will be the known centre from which we measure the variable quantities ϕ, x and x^1, or we might say V is the fixed point, and O, O' and F the variables. Now distances on the right hand of V are always considered as positive or +, and distances to the left as negative or −. Thus if the point O be three inches away from V, we consider that this − 3 ($x = -3$), if the point O' is $1\frac{1}{2}$ inches from V it is + $1\frac{1}{2}$ ($x^1 = +1\frac{1}{2}$). But it is evident that a lens has a focal point on each side of it, one at F' for the position where parallel light incident from the left is brought to a focus, and the other at F, to which parallel light incident from the right is conveyed. Thus a lens has one focus on the right hand of V, and another on the left. There would seem to be no reason why the focal length of a lens should be either positive or negative. One focus has a positive, the other a negative position. To overcome this difficulty the focal distance of the lens is always considered as that formed by parallel light travelling from left to right. In Fig. 7 the light travelling from left to right will be brought to a focus at F' to the right of the lens, and the focal distance V F', or ϕ, is positive or +, and the lens is called a positive lens. If the lens had been concave instead of convex, the focus for parallel light would have been to the left of V, and the focal distance ϕ would have been negative or −; such a lens is called a negative lens.

Assuming as above that VO = − 3 = x, and that $\phi = +1$, our equation for the position of the conjugate foci becomes

$$\frac{1}{x^1} - \frac{1}{(-3)} = \frac{1}{1}$$

which when solved gives $x^1 = +1\frac{1}{2}$, showing that the point O' lies $1\frac{1}{2}$ inches to the right of V.

By the proper attention to these signs the position of any conjugate foci can be obtained with a thin lens of any focus, whether convex or concave, and it will be seen later how exactly the same formula applies equally well to thick lenses, or systems of lenses, however complicated.

It has been pointed out that with a lens a certain portion of the refraction, or bending may be accomplished at each surface; and it will be convenient in the first instance to investigate the action of a lens which is so thin that the interval between its two surfaces may be neglected. Let Fig. 9 represent such a lens where we may consider that both refractions take place simultaneously on the line V′ V V″, instead of at the two surfaces. Let the focal points of our lens be at F and F′. It is required to find the point at which all the light passing through A will meet after having passed through the lens. If we draw a ray of light A F V″, passing through the focal point, it will emerge from V″ parallel to the axis, and in the direction of V″ I; because it is the property of the focal point that light passing into the lens parallel to the axis from right to left will pass through F. Let us also draw from A the ray A V′, parallel to the axis, this will emerge through the other focal point F′, and the point I where these rays meet will evidently be the conjugate focus of A.

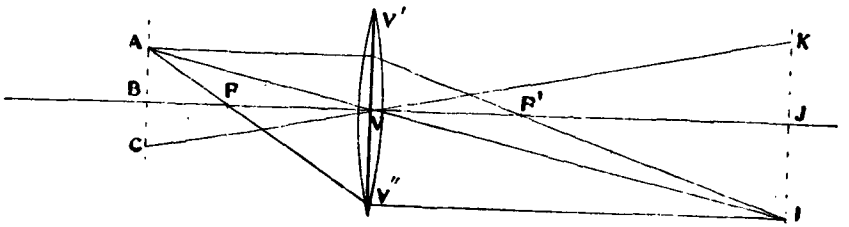

Fig. 9.

It will now be noticed that the line A I joining the conjugate points, passes through the centre of the lens V, proving that a ray from A would pass through the centre of the lens without refraction. It is universally true for infinitely thin lenses (subject to the limitation as to very oblique rays already mentioned), that a ray passing from any point to its corresponding conjugate point will pass through the centre of the lens without refraction.

If a series of points on the line A B C, at right angles to the axis, be taken, and their conjugate points be ascertained by the system adopted in Fig. 9, it will be found that all these conjugate foci lie on the line I J K, or that every point on the line A B C has its conjugate point on the line I J K. In fact that the line I J K is conjugate to the line A B C, or as it is generally expressed, a plane at A B C, at right angles to the axis, has its conjugate plane also at right angles to the axis at I J K. It is obvious that the position of these planes being known, a line drawn from any point, as for instance C, through the centre of the lens V, will indicate the position of its conjugate point K, in the conjugate plane I J K.

To those interested in Geometrical problems, it will be readily seen that the equation

$$\frac{1}{x^1} - \frac{1}{x} = \frac{1}{\phi}$$

is immediately deduced from Fig. 9.

Having examined the case of a thin lens, let us proceed to note what occurs in a lens that is not thin. Suppose we commence to geometrically construct a diagram, Fig. 10, by means of which, as in the case of a thin lens, we may ascertain the position of the plane that is conjugate to the plane A B C; and the point that is conjugate to the point A. We might draw the ray A F through the focus, meeting the lens at S; we know that after it has passed through both surfaces of the lens this ray will emerge in a direction parallel to the axis of the lens; but we do not know from what point upon the second surface it will proceed, and therefore, although we know its direction, we do not know at what distance from the axis it will be situated. Again, if we were to draw the ray A T parallel to the axis, we know that this will pass out of the second surface in a direction through the focal point F'; but, as before, we do not know from what point it will emerge. It is only in thin lenses that a ray will pass through the centre without refraction, and thus this method of demonstration is useless, and consideration will show that, with a series of lenses, the plan would be even more impracticable; whilst analytical methods on this basis are still more hopeless. The German mathematician, Gauss, has, however, conceived a theory, by which all the simple methods applicable to thin lenses may be applied to lenses of any

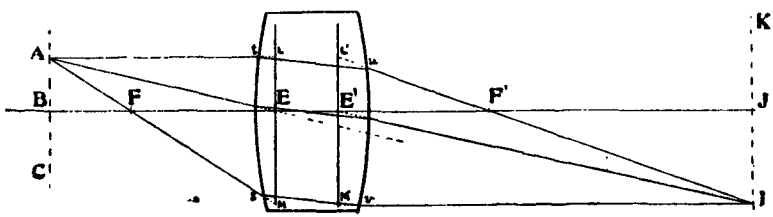

Fig. 10.

tkickness, and any number, however complicated. It is this system that I will now explain. It must always be borne in mind that the method does not apply to uncorrected lenses, as it only deals with central light, as previously explained.

THE EQUIVALENT PLANES.—In any system of lenses there are two planes, at right angles to the axis of the lenses, from which all the refraction *appears* to take place. We have assumed in Fig. 9 that the lens was so thin that it might be considered to be a straight line, and that all the refraction, or bending, took place upon that line (V' V V'' Fig. 9). The discovery of Gauss shows that in any combination of surfaces or lenses the same simple laws that govern the action of thin lenses may be applied. All that is required is that the single line or plane that is taken to represent the thin lens, shall be replaced by two lines or planes situated at certain definite positions, dependant upon the composition of the optical system under consideration. These planes I prefer to call the *Equivalent Planes*, and the points where they cut the axis the *Equivalent Points*.*

* In the case of an optical system where the last medium into which the light passes is not the same as the first, there are two pairs of planes, each possessing certain characteristics, and called respectively "Principal" planes and "Nodal" planes. Where, however, as in the case of most optical instruments, the light passes from air through the optical system into air, and the first and last media are the same, the Principal and Nodal planes merge into one pair, possessing the properties of both, and I prefer to call them when thus combined the Equivalent planes. It simplifies nomenclature because the Equivalent Focus, a term in general use, is the focal length of a lens system measured from the Equivalent plane.

Equivalent Planes have three properties:

(1). *The two planes are conjugate to each other*, that is to say, all light which before entering the lens system, proceeds towards a point on the first Equivalent plane, will, after having passed through, emerge as if it came from a point on the second Equivalent plane.

(2). *Any point on the first equivalent plane*, as L, fig. 10, *has its conjugate point on the second equivalent plane at a point*, as L', fig. 10, *at an equal distance from the axis*: i.e., L E = L' E'.

(3). *Any ray of light incident in a direction towards the first equivalent point*, E, fig. 10, *will emerge*, after having passed through the entire optical system, as if it came *from the second equivalent point* E', fig. 10, *and in a direction parallel to the incident ray.*

By making use of these properties we shall be now able to ascertain, in fig. 10, the position of the plane I J K, conjugate to A B C, and of the point I, conjugate to A. Let L E M and L' E' M' be the first and second equivalent planes of the lens; from A draw the ray parallel to the axis, meeting the first equivalent plane at L; we know that this ray will emerge as if it came from L', where E L = E' L', we also know that, entering parallel to the axis, it will emerge through the focal point F'; it will consequently proceed in the direction L' F' I; the actual course of the light, within the lens chosen, is from *t* to *u*; if the lens had been of a more complex nature the course of the ray might have been less simple, but in any case the apparent direction is from A to L and from L' to I. The ray from A to the first equivalent point E emerges as if it came from E' and in a parallel direction. The ray from A through the focal point F, meeting the first equivalent plane at M, will emerge from M' where M E = M' E' and in a direction parallel to the axis. The point I, when the rays meet, will be the conjugate focus of A, and the plane I J K, at right angles to the axis, will be the conjugate plane to A B C. Thus it will be noticed that the principle governing the action of a complex system is precisely similar to that of a thin lens.

If we take a thin lens, of the exact refracting power of the entire system, and place it in the position of the first equivalent plane while we are considering all rays of light *entering* the lens system; and then, when considering the rays that *emerge*, we shift it into the position of the second equivalent plane; we can apply all the simple methods of a single thin lens to thick lenses or any number of lenses. It is also evident that the focus, or focal distance, must be measured from these two planes, because the focus is a measure of the bending, or refracting, power of the lens, or lens system, and as the bending or refraction, considered as a whole, takes place from these planes, it is evident that no true measure of the focus can be given except the distance of the focal point from these planes. Light, parallel to the axis, which enters the lens (fig. 10) towards L will be refracted from L' to F', and therefore the focal distance is E' F', or similarly E F; and a thin lens with the same focal distance V F' (fig. 9) equal to E' F' (fig. 10) will give precisely the same optical results, as the lens in fig. 10,

with the sole exception that there is a space lost, as it were, in the gap between the two equivalent planes.*

Thus it is evident that the simple formula, for the positions of the conjugate planes, is applicable to the thick lens or lens systems, with the sole alteration that the distances are measured from the two equivalent planes respectively, instead of the lens centre.

$$\frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi}$$

$x = \text{E B}$
$x' = \text{E}' \text{J}$
$\phi = \text{E F or E}' \text{F}'$

Thus taking one previous example—when $x = (-3)$ and $\phi = +1$ therefore $x' = +1\frac{1}{2}$.

It is the function of the microscope to produce an enlarged or magnified image of an object in order that we may study its minute structure; and having explained the elementary theory upon which lenses refract, we must consider what are the necessary optical conditions to produce a clear image.

Let L E M, L' E' M' (fig. 11), represent the equivalent planes of some lens system, and F and F' the focal points on either side. The system may be one or a number of lenses. It may be complicated or simple, it makes no difference to

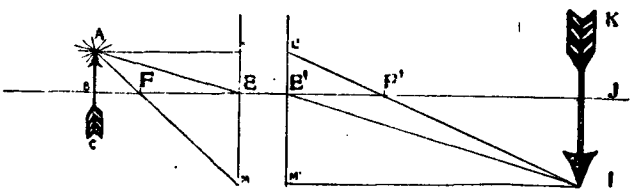

Fig. 11.

the problem. The shape and arrangement of the lenses is designed by the optician to correct those errors which this theory assumes to have been annihilated. All we require to know, are the four cardinal points, F, E, E', F'. Let A represent a point upon an object A B C. This point, we will assume, is brilliantly illuminated, and is radiating light in all directions. Let us suppose that of this particular light, the cone L A M is all that can pass through the lens system. We know that all the light included in this cone will be conveyed to its conjugate point I; we also notice that the point I cannot receive any light that passes through the lens system, except what is included in the cone L A M, for instance, no ray of light that passes through the point C can reach the point I, because we know that any such ray will be refracted by the lens system to the point K. Thus the point I being illuminated only by the light radiated from the point on the object at A, it will be a reproduction of that point. If A is bright, I will be bright; if A is green, I will be green. And thus every point in the object A B C will have a corresponding point in the plane I J K, and an exact picture or image of the object A B C will be formed on I J K. If a piece of white paper be placed

* The term equivalent focus is generally given to the focal length of a lens system. This merely means the measure of the refracting, or bending, power of a lens system—its focus—but its focus measured from the correct place. That is to say, from the first equivalent plane on one side of the lens, and from the second equivalent plane on the other

in the plane I J K, the image of the object, if sufficiently brightly illuminated, will be visible upon the paper. An image of this kind, which is actually existing in space, is called a *real* image.

A second form of image, called a *virtual* image, is formed in another manner.

Suppose the lens system to be similar to that of fig. 11, but place the object at A B C (fig. 12) and we shall find, by adopting our previous method of fig. 10, drawing the ray from A parallel to the axis to L it will emerge from L' through F', by drawing the ray from A to E, this will emerge from E' parallel to A E, and it will be noted that the conjugate point to A is now at I, because the rays proceed as if they came from that point. There is no real image of the object A B C at I J K, but the light emerges from our lens system as if there were, and the eye looking from the right-hand side would see the object A B C, as if it really existed at I J K. This is called a *virtual* image. The lens system, depicted fig. 12, is a simple microscope or hand lens and it will be noted that the eye placed on the right hand of E, say between E and F, will see an enlarged image of the object A B C at I J K, consequently the system acts as a microscope and magnifies the object.

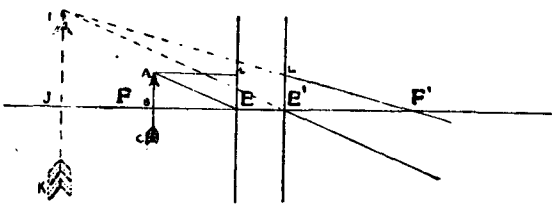

Fig. 12.

THE SIMPLE MICROSCOPE.—The simple or hand microscope consists of a single lens or a combination of lenses, so close together that they may be considered as one. It may be made of two or three lenses, either cemented or in close juxtaposition, but when this is done it is for the purpose of improving the quality of the image by correcting the aberrations alluded to, and does not affect the elementary optical principles upon which the image is formed. It is necessary to know the shape and composition of a lens system in order to calculate the position of its equivalent planes. But as they may readily be found by experiment it is unnecessary to know the precise construction for elementary purposes; what we require are the positions of the equivalent planes, and focal distances.

Lenses of different shapes, and different combinations of lenses, have their equivalent planes in widely different positions and it will be evident later on how this fact is made use of in the construction of compound microscopes. Fig. 13 shows a series of lenses with the position of their equivalent planes indicated.

Let us now consider certain matters connected with the formation of images by a lens system. It is unnecessary to draw the lens system itself, merely indicating it by its two equivalent planes, E E', fig. 14 and 15, and its two foci, F F.'

In fig. 15 we have the case of an object, situated at A B C, on the left hand of the focal point, its image at I J K, on the right hand of the other focal point. If we move the object A B C towards the lens, its image will recede further away from the lens, until when the object is in the focal plane, its image will be at an infinite distance on the right-hand side, and the rays emerging from any point on the object through the lens will be parallel (or may be said to meet and form an image at infinity). This image is a real image of the object which, if we had inserted a screen as for instance at I J K, fig. 15, we could have demonstrated, is actually projected into space. If we proceed to move the object A B C still closer to the lens beyond the focal point, then, as in fig. 14, we obtain a virtual image I J K, which as the object is approached from left to right still further towards the lens, moves from left to right from infinite distance up to the second equivalent plane; when the object is at a distance half-way between the focus and the first equivalent plane, its virtual image is at the first focal plane, when the object has been moved up to the first equivalent plane, its image is in the second equivalent plane. It is well for the student to thoroughly grasp the

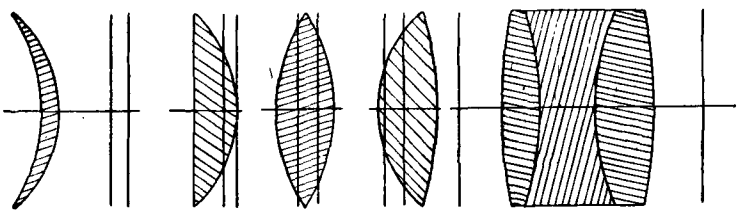

Fig. 13.

relative positions of the two conjugate planes, and a few examples should be considered, which may either be sketched geometrically or worked out algebraically from the formula

$$\frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi}$$

where x = distance of object plane from first equivalent plane (E B) x' = distance of image from second equivalent plane (E' J) and ϕ focal distance from E F or E' F'.

Suppose $\phi = +1$ inch

when $x = -\frac{1}{2}\ x' = -1$

$x = -\frac{1}{5}\ x' = -\frac{1}{4}$

$x = 0\ x' = 0$

$x = +\frac{1}{3}\ x' = +\frac{1}{4}$

$x = 1\ x' = \infty$

It is noticeable that, as the object is moved from left to right, its image will also move from left to right, and *vice versa*—i.e., the object and its image always move in the same direction.

The two figures 14 and 15 represent the two methods of image formation in the compound microscope. Fig. 14 is the method which is always employed in the simple or hand instrument. If we consider what are the properties of the eye, we shall observe why this must be so. The normal eye is an optical instrument, which forms an image within itself of external objects; and is so constructed that it will give a clear picture of everything situated between infinite distance (such as a star), and a distance of about ten inches from the eye, called the near point. That is to say, it will produce a clear vision by means of rays

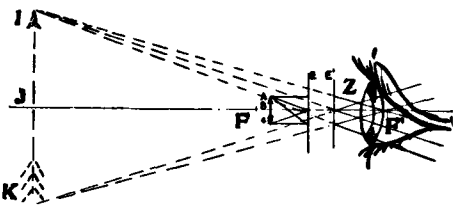

Fig. 14.

diverging from an object at a great distance, which may be considered parallel, or by means of rays diverging from any point not closer than about ten inches. The normal eye will not give clear vision by means of any other rays, as for instance, those converging to a point, or those diverging from a point one inch from itself. Consequently if we form an image by means of an optical instrument, that image must be situated in front of the eye at a distance not nearer than about ten inches. If the eye were placed at the point M, fig. 15, it could not see the point C of the object, because the rays of light from that point are converging to a point K; the only position in which the eye could be placed to see the image of the point C would be at such a position as Z, at least 10 inches away to the right of K, so that the rays from the point K should be diverging from a point at least ten inches from the eye. In the case of fig. 14, the eye may be placed at the position Z, close to the lens and will see the image of the point C, because the

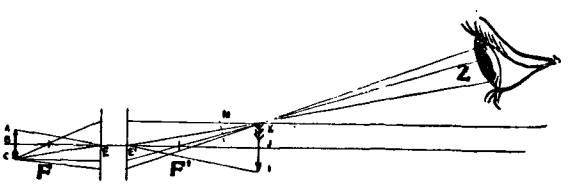

Fig. 15.

rays are diverging, as if they came from the virtual image at K, supposed to be at least ten inches away from Z. These then are the two methods by which a lens can produce an image visible to the human eye. Fig. 14, in which the object is placed between the focus and the lens so that a virtual image is formed not less than ten inches away from the eye. Fig. 15, in which the object is placed further away from the lens than its focus, so that a real image is formed on the other side of the lens and the eye is placed not less than ten inches away from that image.

Now it is evident, that in the latter case the eye placed at M (fig. 15) could only collect a very small number of the rays that pass through the lens, and that although it might be able to see the point C, it could see but a very small portion of the object at one time, and the points B and A could not be observed while C was in view.

On the other hand, in fig. 14, it will be observed that the whole body of the light from the lens passes through a comparatively small area in the neighbourhood of Z, and if the eye be placed at this point it will collect all the light from the object; and the whole of the object A B C will be visible at one time, apparently emanating from the virtual image I J K. This is the reason why the method of using a lens or system of lenses, for a simple or hand microscope, is always that shown in fig. 14, and the position which the eye unconsciously takes up at Z, in order to secure as large a field of view as possible, is called the *eye point.*

In moderately thin single lenses the eye point is generally theoretically within the surface of the lens, and the closer the eye can be placed to the lens the larger the field of view. It will be seen that in a compound microscope the eye point is outside the instrument.

Magnifying Power.—To ascertain the magnifying power of a microscope might appear to be a simple matter, but it is necessary to clear our ideas in order to thoroughly grasp the principles upon which it depends. Magnifying power is a comparison of the actual size of an object with that of the picture of it formed by the microscope. The size of the picture, divided by the size of the object, represents the magnifying power. It is always stated in what are called "linear dimensions." Thus a 1 inch square if magnified twice would be understood to be a 2 inch square; as a matter of fact four 1 inch squares could be contained in the area of a 2 inch square, but we should not say in dealing with the microscope that it was magnified four times, but only twice.

But now we come to the question, "What is the size of any object?" We say that a halfpenny is an inch in diameter. Where we are dealing with actual images formed in space by a lens (see fig. 15) in such a manner that a sheet of paper may be held at the position I J K, and the image be investigated, this method of expressing size by inches without reference to any other element is satisfactory.

We can take a foot rule and measure the actual image on the paper at I J K, and compare it with the measurement of the object in inches in order to see how much the object has been enlarged.

But in a simple microscope, as we have pointed out, the image is not formed in this manner; there is no actual picture that we can measure with a foot rule. The light is coming into the eye as if it came from a picture, but it is only a *virtual* image, and measurement in this way would be impossible. It can be calculated, but in this case we must introduce another element into consideration, namely, the distance of the object from the eye.

We sometimes hear that the moon is the size of a plate, a Dutch cheese, or a piece of chalk. None of these give an adequate idea of its apparent size. It

will be found that a good sized pea, held at arm's length, will just obliterate it: and it is evident that in order to explain the apparent size of any object, we must compare it with some known object at a definite distance from the eye.

If we were to look at a pea through a microscope, and this microscope produced a picture of it as large as the moon and at a distance equal to that of the moon; the picture itself would be larger than the pea, but being so far away it would not appear to be so. A two inch ball at a distance of twenty inches would appear to be the same size as a one inch ball at ten inches; and in order to form a correct comparison of their relative sizes it is evident that we consider both at the same distance from the eye.

This applies to the comparison of an enlarged image, formed by a microscope, with the object itself. In considering how much that object is magnified we must consider both the object and its image at the same distance from the eye.

For convenience a standard distance has been adopted. With normal eyes there is a position, varying from about eight to twelve inches from the observer,

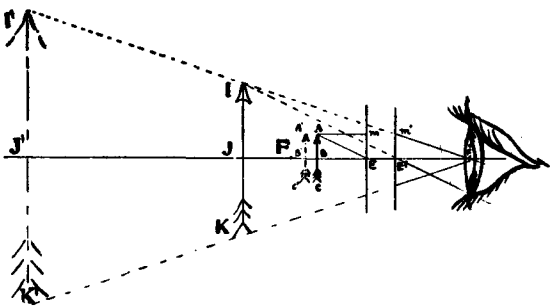

Fig. 16.

that is the most comfortable place at which to place any small object under examination, and as being a convenient number, the distance ten inches has been chosen as the standard distance. To say that a microscope magnifies six times or diameters, means that it shows the object six times as large as that object would appear when held at ten inches from the eye.

The importance of clearly appreciating these simple points will be understood when it is pointed out that in a hand microscope we do not know how far from the eye the virtual image is actually formed.

In fig. 16 let E E' be the equivalent planes of a hand microscope, and F F' its foci, and let A B C be an object placed upon the right-hand side of the focus F. Draw A *m*, parallel to the axis, this ray will emerge from *m'* at a distance from the axis *m'* E' = *m* E, but being incident parallel to the axis, it will emerge through F', thus its direction will be I *m'* F'.

Draw the ray A E to the first equivalent point, it will emerge from E' and in a direction parallel to A E; the point I, where these rays meet, will be the position of the virtual image I J K. But suppose we had held our object rather further

from the lens, at the position A′ B′ C′, the virtual image would then have been formed at I′ J′ K′. Thus according to the exact distance of the object from the microscope, so will the virtual image vary in position. We know, because the normal eye does not clearly see objects much closer than eight or ten inches, that the virtual image I J K must not be closer to the eye than this distance, but it may be at any greater distance to the left, and will still be as clearly visible. Thus it is, that we do not know at what exact distance from the eye the picture is actually formed. But we shall notice one important fact. The ray of light from A, after passing through the lens, proceeds in a direction I *m′* F′ from its virtual image I J K to the eye, and a ray of light from A′ parallel to the axis must also proceed in the same direction I′ *m′* F′, so that wherever the point I′ is it will always be on the line I′ I F′, and wherever the virtual image is, due to the different position of the object, it will always be included in the angle I′ F′ K′, and will, if the eye be placed at F′ always have the same *apparent* size whatever its real size may be.

If the image at I J K, ten inches from the eye, is three inches in size, the image at I′ J′ K′ twenty inches away will be six inches, but they will both appear to the eye to be exactly the same; in fact, the image formed upon the retina of the eye will be the same.

Thus in considering how much the image, formed by the microscope, is larger than the object would appear at the standard ten inch distance, it is evident we must measure the size of the virtual image, when it is formed ten inches away from the eye, because, as we pointed out before, to compare the size of two objects they must both be observed at the same distance. The moon at 250,000 miles appears no larger than a pea at thirty inches, but we know that it is really many million times the size, and to compare their relative sizes, we should have to place them at an equal distance from the eye.

Therefore we note that, wherever the virtual image actually is formed by the microscope, we must always consider it, for the purposes of the magnifying power, to be at a distance of ten inches from the eye. And to ascertain the magnifying power we have only to measure the virtual image, at this distance, and then divide it by the object itself. If y be taken to represent the distance A B in fig 16, and y' to represent the distance I J, when the image is at ten inches from the observer's eye, then $\frac{y'}{y} \ldots m$, or magnifying power. We have, however, previously pointed out that we cannot take a foot rule and measure the distance y', but by a very simple geometrical proof we can establish a ratio between these distances which gives us their value as regards the focus of the lens system or microscope. It is evident that the triangles I J E′ and A B E are exactly similar triangles, although one is larger than the other, because the line I E′ is parallel to A E by construction, the sides A B, B E are respectively parallel to and coincident with I J and J E, therefore the similar sides in both triangles are in proportion.

$$\frac{I\,J}{A\,B} = \frac{J\,E'}{B\,E}$$

but, $\frac{I\,J}{A\,B} = \frac{y'}{y}$ and $\frac{-\,J\,E'}{-\,B\,E} = \frac{x'}{x}$

therefore, $\frac{y'}{y} = \frac{x'}{x}$

and we know that $\frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi}$

Multiply both sides of this equation by x' and we obtain :

$$1 - \frac{x'}{x} = \frac{x'}{\phi} \text{ or } \frac{x'}{x} = \frac{\phi - x'}{\phi}$$

Therefore, $m = \frac{y'}{y} = \frac{\phi - x}{\phi}$

This formula gives us the magnifying power of the lens, in terms of the focus of the lens, and the distance $\phi - x'$, which it will be noticed is the distance J F' of the image from the second focal point. But the standard position at which, for stating magnifying power, we assume the image I J K to exist, is ten inches from the eye ; therefore, if the eye be placed in the second focus of the lens, at the point F', the distance $\phi - x'$ is ten inches, and the magnifying power is given by the formula

$$m = \frac{10}{\phi}$$

With long-focus hand lenses the eye is not placed near this point, but is closer to the lens, at the position as near to the " Eye point " as possible, which in single lenses is generally inside the lens itself. Suppose the eye to be placed $\frac{1}{2}$ an inch away from the second Equivalent plane of the lens, the distance x' will obviously be $-9\frac{1}{2}''$, and the equation for magnifying power becomes

$$m = \frac{\phi + 9\frac{1}{2}}{\phi}$$

If the focal length of the lens be three inches :

$$m = \frac{3 + 9\frac{1}{2}}{3} = \frac{12{\cdot}5}{3} = 4{\cdot}166$$

If the focal length of the lens ϕ be one inch :

$$m = \frac{1 + 9\frac{1}{2}}{1} = 10\frac{1}{2}$$

For microscopical purposes a short focus lens is generally used, and the eye in this case is not far from the second focal point, so that it may be considered to be at this point without serious error, still the fact that it is not necessarily there should be borne in mind where accurate calculations are required. However, in general we do not consider this qualification, and the magnifying power of a hand microscope is given by the equation

$$m = \frac{10\text{-inches}}{\phi}$$

It will be noticed that the shorter our focal distance ϕ, the greater is the magnifying power. If the focus be $\frac{1}{2}$ inch, magnifying power is 20, — $\frac{1}{4}$ inch, 40, and so on, and in fact the only factor upon which magnifying power depends is ϕ, or focal length.

It will be remembered by referring back to figs. 4 and 5, that the method adopted to bend or refract light to a point, was by means of employing a curved surface instead of a flat one. and it is obvious that the more curved our surface is, the greater refraction we shall obtain. That is to say that the shorter the radii of curvature of the surfaces of a lens, the greater will be its refracting power, and the shorter will be its focus.

Thus, to increase magnifying power, we must shorten the focus of the lens, and to shorten the focus of the lens we must deepen the curves or shorten the radii of curvature. But when we deepen the curves of a lens certain serious practical dsadvantages occur. To make a *single* lens $\frac{1}{8}$ inch focus the radii of curvature would have to be about $\frac{1}{12}$ inch, and the diameter of a lens with such curvature, even if it were made a complete sphere, could not be more than $\frac{1}{8}$th of an inch. Its magnifying power would be 80 diameters, and the object would almost have to touch the surface of one side, while the eye was exceedingly close to the other. Thus, although such high-power single microscopes are occasionally made, they are only used with great difficulty, suffer from many other disadvantages, and could not give a magnifying power much greater than about 80 diameters, while many of the investigations for which the microscope is required, demand a power of at least 1,000 diameters. To meet this want the Compound Microscope has been designed.

The Compound Microscope.—Before going into the question of the optical means whereby the additional magnifying power of the compound microscope is obtained, without the disadvantages of the simple instrument, let us look at the general mechanical construction of a compound microscope in its simplest form. The main portions of a Compound Microscope (fig. 17) consist of—

(A) *The Body* which carries two systems of lenses.

(B) *The Eyepiece*, which is that system of lenses nearest to the eye of the observer and is made to drop loosely into the upper end of the tube, so that eyepieces of different power may be readily inserted without interfering with the adjustments of the instrument.

(C) *The Object Glass*, which is the system of lenses nearest to the object and which is attached to the lower end of the microscope or *Nosepiece* (D) by a standard screw.

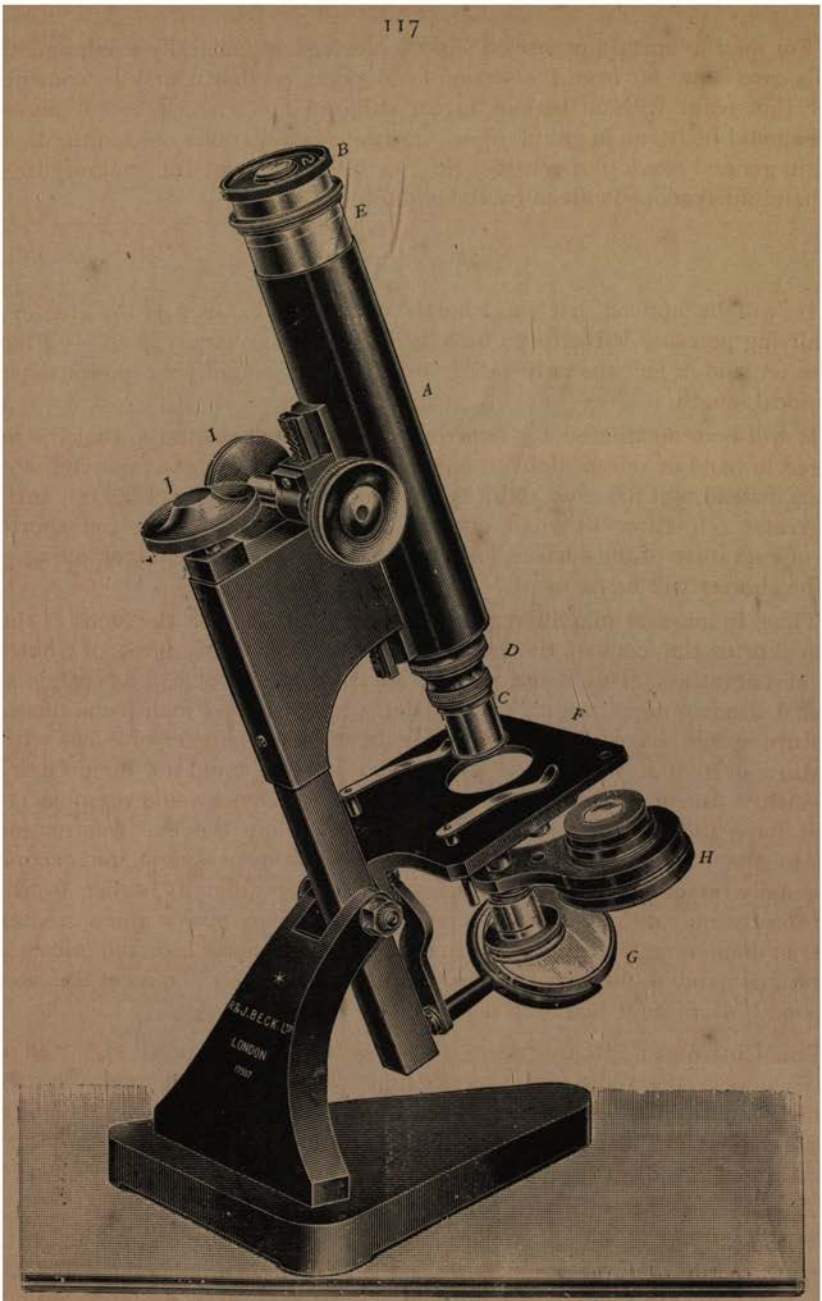

Fig. 17.

(E) *The Drawtube*, a telescopic tube in the body to enable the eyepiece and object glass to be separated from one another.

(F) *The Stage*, a fixed platform arranged below the *body*, upon which the object under examination is placed and provided with an aperture in the centre, so that the light may be thrown through the object by a

(G) *Mirror* which is attached to the instruments a few inches below the stage.

(H) *The Substage*, a fitting between the stage and the mirror for carrying various apparatus for illuminating the object by special methods.

The adjustments of the microscope are

(I) *The Coarse Adjustment* for moving the *body* up and down to and from the object in order to place the optical portion of the instrument in focus, or in the position required to give a clear image. It is usually effected by a rack and pinion movement.

(J) *The Fine Adjustment* which moves the body in exactly the same way as the coarse adjustment but is of a much more delicate character and is generally dependent for its action on a fine screw, either in connection with a lever motion or acting directly upon the moving parts.

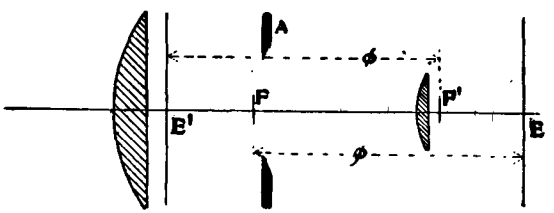

Fig. 18.

Other adjustments are supplied to the more expensive instruments for giving delicate movement to the illuminating apparatus and to the object.

In order to consider the optical construction of the compound microscope, it will be necessary to point out the position of the equivalent planes and foci in a typical eyepiece and a selected series of object glasses.

It will be observed in the course of an investigation into equivalent planes, that their position is capable of great alteration according to the arrangement of the various component lenses. A striking example of this is the Telephoto Lens, used for photographing very distant objects, where the equivalent planes are thrown so far in front of the lens, that although its focus is very long, the camera used need not be unduly large, as the lens itself is at a great distance behind its equivalent planes from which its focus is measured. We shall see further on that if the compound microscope be considered as a complete system, its equivalent planes lie outside all the lenses.

Fig. 18 shows the form of eyepiece in almost universal use, composed of two single plano-convex lenses, both flat surfaces being towards the eye. Between these lenses and near the focus of the smaller lens is a circular diaphragm (A) to limit the field. The equivalent planes of this system are situated in an unusual manner.

The first equivalent plane is at E, while the second is at E', and they have actually crossed. The focus for parallel light entering the lens from left to right is at F', and the focus for parallel light in the opposite direction, F.

Fig. 19 shows a series of object glasses with their equivalent planes and foci.

In the 4", $\frac{4}{10}$th, $\frac{1}{6}$th, the equivalent planes are not crossed, but as in an ordinary single lens shown in fig. 10; in the $\frac{2}{3}$rd and $\frac{1}{12}$th it will be noticed that the two Equivalent planes are crossed as in an eyepiece. In all cases the lenses are positive lenses, because the point to which parallel light, travelling from left to right, through the lens, is converged, is on the right-hand side of the first equivalent plane. In order to illustrate the arrangement of a compound microscope it will be well to take an eyepiece and one object glass as a typical case. Let us take the eyepiece shown in fig 18, and a typical object glass, and place them at a certain distance from each other, as in fig. 20. (N.B.—The longitudinal distances are in most of the figures shortened in order to include them in the size of the paper.)

Although the lenses are indicated, the principal planes and foci of the two systems are the only portions used for the purpose of ascertaining the course of the rays of light. The object is situated at A B C, at a position slightly to the left of the focus (F_1) of the first lens system or object glass. Draw the ray A *m* parallel

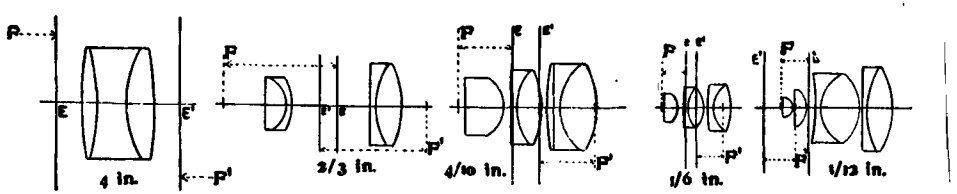

Fig. 19.

to the axis to the first equivalent plane of the object glass; this will emerge from a point *n* on the second equivalent plane, equidistant from the axis to *m*, and being parallel to the axis will pass through the focal point F'_1. Draw the ray A E_1, this will emerge from E'_1 and in a direction parallel to the ray A E_1, and the point A' where the rays meet is the conjugate point to A, indicating where the image of the object A B C will be formed, after having passed through the object glass. If the eyepiece were removed this image might be seen on a screen at A' B' C'. Let us now see where the image A' B' C' will be when projected through the eyepiece. The procedure is the same, but the fact that the equivalent planes are crossed makes it appear somewhat more complicated. The ray *n* A' meets the first equivalent plane of the eyepiece at *y*, and therefore will emerge from a point on the second equivalent plane *v*, equidistant from the axis, but we must now learn in what direction. Draw a line from A' to the first equivalent point E_2; this will emerge from E'_2, and in a direction E'_2 I parallel to A' E_2. The conjugate point to A' must consequently lie upon this line. Now draw a line A' *s* to the first equivalent plane parallel to the axis, this will emerge from a point *t* on the second equivalent plane equi-distant from the axis, and it will proceed in a direction through the focus F'_2; the point where this ray cuts the ray E'_2 I, is the conjugate point of A', and the line joining the points *r* and I will give the direction of the final emergent ray

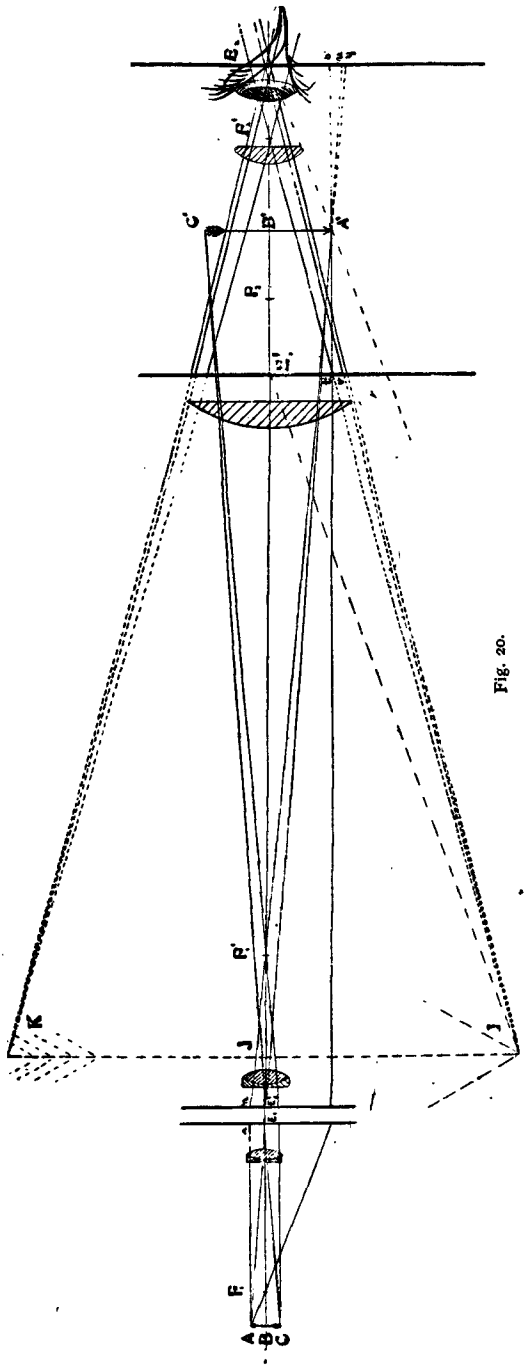

Fig. 20.

corresponding to the ray n F'_1 y. Similarly the ray E'_1 A', meeting the first equivalent plane at u will emerge from a point v on the second equivalent plane, and by joining the points I v we obtain the direction of the emergent ray corresponding to E'_1 A'. In a similar way the rays from B may be taken to B′ and J, or from any other point on the object to its conjugate point on the final image, I J K. The image made by the object glass lying at A′ B′ C′ is a real image which enters the eyepiece, and the eyepiece gives a virtual image of this at I J K, ten inches away from the eye, the eye being placed a short distance above the eyepiece at the eyepoint, where the maximum number of rays cross the axis.

This is the manner by which the optical portions of a microscope combine to produce the image observed when looking through the instrument.

When the instrument is used for micro-photography we do not require a virtual image projected into space for the eye to look at, but we require a real image which, when thrown upon a photographic plate, shall be recorded by the sensitized chemical surface. For this purpose the eyepiece may be dispensed with and the photographic plate may be placed at the point A′ B′ C′, where the real image is produced by the object glass, or, if this image is not large enough, the object A B C may be brought closer to the object glass, thus giving its image A′ B′ C′ further away to the right and consequently more highly magnified. Or for reasons connected with the fact that an object glass is corrected by the optician to produce the finest image at one place it is somewhat better to adjust the microscope exactly as though it were to be used for direct observation, and to replace the ordinary

eyepiece by one specially made to produce a real picture of the image A′ B′ C′ upon the right of the instrument, which acts essentially as if it were another object glass.

Let us now observe what are the advantages of the compound microscope which the simple instrument does not possess.

The first important advantage is the increased magnifying power. There are in the compound microscope two complete optical systems, the object glass which gives us an enlarged picture of the object A B C at A′ B′ C′ (fig. 20), and the eyepiece which gives a further enlarged virtual picture I J K of the image A′ B′ C′ formed by the object glass. Thus it is obvious that if the object glass gives a picture A′ B′ C′ say ten times the size of the object A B C, and the eyepiece gives an image I J K say five times that of the image A′ B′ C′, the magnifying power of the entire instrument will be fifty; that is to say, the magnifying power of the object glass multiplied by the magnifying power of the eyepiece. It is thus evident that a great increase in magnifying power is obtained by using the compound instead of the single or hand microscope. Now, by comparing fig. 20 and fig. 14 it will be observed that the eyepiece acts in precisely the same manner as a hand or single microscope; it is simply a hand microscope used to magnify the image formed by the object glass, and we know that if the eye of the observer be situated at the second focus of such an optical system the magnifying power is $m = \frac{10}{\phi_2}$ where ϕ_2 is the focal distance of the eyepiece. In the eyepiece that we have selected $\phi_2 = 1{\cdot}4$ and $m = \frac{10}{1{\cdot}4} = 7{\cdot}14$.

What then is the magnifying power of the object glass. It will be observed that the object glass of our microscope in fig. 20 is a lens used in exactly the same way as that in fig. 15, and it will be further observed that the relation of the magnifying power to the distance of the object and image from their respective equivalent planes proved to be correct for a lens giving a virtual image as at figs. 14 or 16 is exactly the same for a lens giving a real image of the object as at fig. 15. If the student will apply the same reasoning as that given on pages 114 and 115, but to fig. 15 instead of fig 16, it will be seen also that

$$\frac{y'}{y} = \frac{x'}{x}$$

and we proved earlier on that

$$\frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi}$$

In fact both these formulæ are universal formulæ for all lens systems. We can in the last formula multiply both sides of the equation by x' and we get

$$1 - \frac{x'}{x} = \frac{x'}{\phi}$$

or we may write this

$$-\frac{x'}{x} = \frac{x'}{\phi} - 1$$

$$\text{or } \frac{x'}{x} = -\frac{x'-\phi}{\phi}$$

but $\frac{y'}{y} = \frac{x'}{x}$ therefore the magnifying power $\frac{y'}{y} = -\frac{x'-\phi}{\phi}$

$$\text{or } m = -\frac{x'-\phi}{\phi}$$

The distance x' is the distance $E'_1 B'$ of the image $A' B' C'$ from the second equivalent plane of the object glass, and ϕ is the distance of the second focus from the second equivalent plane of the object glass $E'_1 F'_1$. Therefore $x' - \phi$ is the distance $F'_1 B'$ of the image $A' B' C'$ from the back focus of the object glass. Now we showed, in considering the case of a single microscope, that if the image $A' B' C'$ was situate in the first focus of the eyepiece F_2, the magnifying power would not be altered, so that for this purpose the image may be considered to be in this position, and the distance $x' - \phi$ becomes the distance $F_1' F_2$, or the distance between the back focus of the object glass and the first focus of the eyepiece, and the magnifying power of the object glass is

$$m_1 = -\frac{F'_1 F_2}{\phi_1}$$

with a $\frac{2}{3}$rd object glass and a distance of six inches between foci of two systems

$$m = -\frac{18}{2} = -9$$

And the magnifying power of the whole instrument is the multiple of the powers of the object glass and the eyepiece, and becomes

$$m = -\frac{F'_1 F_2}{\phi_1} \times \frac{10}{\phi_2}$$

or in the case of $\frac{2}{3}$rds inch object glass and 1·4 inch eyepiece

$$m = -9 \times 7{\cdot}14 = -64{\cdot}26$$

It is now interesting to note that the magnifying power of the *eyepiece* is always the same with the same optical construction. The magnifying power of the eyepiece described will be 7·14 whatever the object glass used or whatever be its distance from the eyepiece.

The magnifying power of the *object glass* will, however, depend upon the position at which the eyepiece is. If the eyepiece be six inches away from the object glass the distance $F'_1 F_2$ which is one of the factors upon which the magnification depends is smaller than would be the case if the eyepiece were to

be moved to a distance ten inches away from the object glass. If the eyepiece be moved further from the object glass to the right than the position shown in fig. 20, the eye looking through the instrument would not see any image until the object glass had been moved a little closer to the object A B C, so that the image A′ B′ C′ might be formed by the object glass in the same position in the eyepiece as before, and the magnifying power of the object glass in the latter case would be increased. The draw tube, with which all microscopes are supplied, increases the distance between the two optical constituents of a compound microscope, in order to increase the magnifying power by this method.

It is evident that if a microscope could be made in such a manner that the distance between the back focus of the object glass and the first focus of the eyepiece were the same whatever eyepieces or object glasses were used, the calculation of the magnifying power would always be simple. Every eyepiece has, as we have pointed out, a fixed magnifying power, and if object glasses were always used to produce an image at the one definite distance from their back focus, each object glass would also have a fixed magnifying power. The determination of the magnifying power would simply be a matter of multiplying together two known quantities. The practical inconveniences, however, of such a plan are too serious to make its adoption advisable, and consequently tables of magnifying powers are compiled to give magnifying powers of microscopes when the different object glasses and eyepieces are used at various distances from each other, or as it is generally expressed when the microscope is used with different tube lengths. Nevertheless, the microscopist requires to carry in his mind an approximate idea of powers, and for this purpose the foregoing important factors which determine magnifying power should be thoroughly grasped.

The powers of eyepieces present no difficulties, they are a fixed quantity; and are usually listed by the makers: in general English eyepieces called Nos. 1, 2, 3, or A, B, C, magnify about 5, 7, 15, respectively, while German eyepieces Nos. 1, 2, 3, 4, 5, magnify more nearly 3, 4, 5, 7, 9, respectively, although foreign makers are less uniform in this respect. If the tube of a microscope be of such a length that the distance between the back focus of the object glass and the first focus of the eyepiece be six inches, the magnifying power of the object glass is obtained by multiplying the reciprocal of the focal length of the object glass by 6.

The following table will give magnifying powers of various object glasses under this condition.

Focus of Object Glass.	Power of Object Glass alone.	Power with Eyepieces. A	B
1″	6	30	42
$\frac{2}{3}$″	9	45	63
$\frac{1}{2}$″	12	60	84
$\frac{1}{4}$″	24	120	168
$\frac{1}{6}$″	36	180	252
$\frac{1}{8}$″	48	240	336
$\frac{1}{12}$″	72	360	504

In order that the above results should be quite accurate, it would be necessary that the mount of an inch object glass should be nearly an inch longer than that of $\frac{1}{12}$ inch, such a plan would be most inconvenient, and we are

obliged to sacrifice ease of calculation to more important practical requirements. In the early days of microscope manufacture it was sought, in order to simplify the calculations, to manufacture the lenses in such a manner that the object glasses were named not according to their real focal length, but according to a system that should render calculation of power simple. This especially applied to low powers. It was assumed that the standard distance between the equivalent planes of the object glass and eyepiece was ten inches, and microscopes were at one time made with tubes of approximately the length to produce this. Lenses were then called by numbers which when divided by this distance, namely ten, gave their actual magnifying power, thus a so-called 4 inch had a real focus of about $2\frac{1}{2}$ inches, the actual magnifying power of this lens was about $\frac{10}{4}$ or $2\frac{1}{2}$, and therefore it was called a 4 inch. This plan answered fairly well as long as all microscopes had a standard 10 inches between the optical systems, but when it was found that for certain work a short microscope tube was most convenient, the same lenses were sometimes used upon one instrument and sometimes on another, and this artificial system of nomenclature, which although correct for one standard length, being based on a purely artificial and erroneous basis, was quite incorrect for ascertaining the power except at this definite distance. Consequently as things stand at present, the ideas of magnifying power are in a somewhat confused state, the more so as many of the foreign manufacturers list their object glasses according to their actual focal length, while most of the English adhere to their original conventional method. For exact work it is best to actually determine experimentally the magnifying power, or for rough purposes to rely upon the tables published in the catalogues of the makers. But it would be advisable for all makers to mark their lenses with the old conventional nomenclature in inches for the convenience of the vast body of workers who are used to the old-fashioned names and also with the correct equivalent focus in millimetres. In the high power lenses the difference between the two methods of nomenclature is scarcely noticeable, because the error in calculations arises from the fact that the distance between the object and the eyepiece, was reckoned from the centre of the object glass to the centre of the eyepiece, instead of the back focus of the object glass to the first focus of the eyepiece, and this error is small, so that it is chiefly in lenses of long focus that the glaring error arises.

We have now to consider the next point of advantage in the compound over the simple microscope, namely the size of the field of view in consequence of the position of the eye point. We stated that in a single lens employed to give a virtual image as in fig. 14, all the light passed through a comparatively small point in the neighbourhood of Z, let us notice more accurately where this point will be.

From every point of our object a bundle of rays is collected by our lens for the purpose of forming our image, for instance if V V′ V″, fig. 21, be the front surface of our lens or system of lenses the cone of light A V V″ is the cone of light from the point A, which forms the image at I and the ray A V′ to the centre of the front surface of the lens will be the axis or central ray of this cone of light and the point Z on the axis of the system where all the axes or centre rays of the

individual cones of rays forming the image cut the axis of this system, will obviously be the point where the total body of light will occupy the smallest area, and will be the point where the eye should be placed to receive the greatest number of light rays that can be embraced by the eye at one time. All these central rays or axes of the individual cones of light pass through a point in the centre of the first surface of the lens or lenses and also through the point Z, therefore V and Z are conjugate points, all the rays passing through the point V will again pass through Z. Thus to find the position of the eye point it is only necessary to take the centre of the first front lens surface or where the first surface cuts the axis and find the conjugate focus to that point. In a single microscope this generally lies to the left of the second equivalent plane, as in fig. 21, and is inside the lens, where the eye cannot be placed. But in an eyepiece this point Z lies well outside the outside lens of the eyepiece and close to its second focus, which is the point at which we should wish to place the eye for calculating the magnifying power. The exact position of the eyepoint varies with different object glasses, but the variation is very small; with the $\frac{2}{3}$rd object glass and the eyepiece which we have selected and a distance of six inches between the back focus of the object glass and the first focus of the eyepiece, the eyepoint is ·43 inch outside the top lens of the eyepiece. With the

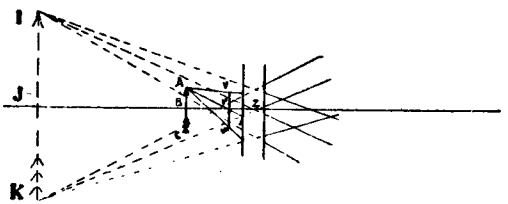

Fig. 21.

same eyepiece and a $\frac{1}{6}$th inch object glass it is ·37 inches above the eyepiece. If the distance between the eyepiece and the object glass be changed, a variation of a somewhat larger amount is caused, but it is not of sufficient amount to affect the question of the calculation of the magnifying power. If the distance between foci had been ten inches instead of six, the position of the eyepoint would have been ·16 inch above the eyepiece, instead of ·43 inch. The advantage of the compound microscope over the single or hand microscope can here be readily seen, inasmuch as the eye can be placed in the eyepoint of the instrument, and if the entire number of rays of light which enter the microscope pass through an area at the eyepoint which is not larger than the pupil of the eye, the whole of the light which enters the microscope will simultaneously enter the eye, rendering a larger portion of the object visible at once, and also enabling a larger bundle of light from each point on the object to enter the eye.

Another and perhaps the most important advantage of the compound over the simple microscope, is what is here referred to, namely, that a much larger cone of light from every point of the object is collected by the instrument. The measure of this cone of light is called the *aperture* of the microscope; but the explanation of this subject is not one that can be entered into in an elementary survey. It is interesting to note however, that the fineness of structure that can

be rendered visible by the microscope, is dependent upon this question of the aperture or the size of the cone of light that can be collected from each point of the object. It might be supposed that details, however fine they were, might be rendered perceptible if only the magnifying power were sufficient, but this is not the case. As the power of an object glass is increased so also must be its aperture, otherwise although it will show upon a larger scale, objects that could be seen with a lens of less power, it will not depict smaller objects or more detail in the same objects; and, as a matter of fact, the power of seeing minute structure is not limited by magnifying power. Lenses of higher magnifying power than those in general use can be made, but they are useless, because we cannot get the necessary additional aperture required for their profitable employment.

If the compound microscope be considered as if it were one optical system, and not, as we have done, as two systems (the eyepiece and the object glass combined together), it presents some very peculiar optical characteristics. The positions of the two equivalent planes will be found to be outside the whole instrument as depicted in fig. 22, the whole of the microscope being inside the space between the two equivalent planes. Thus all light entering towards F

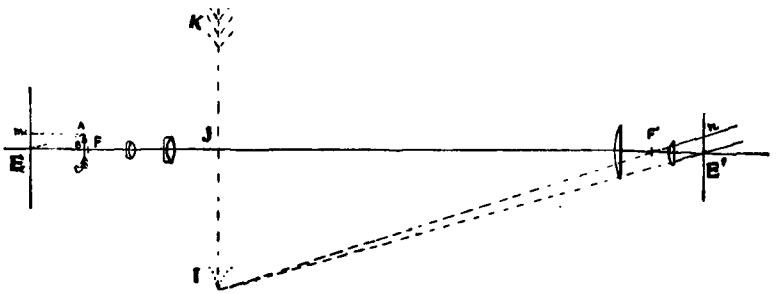

Fig. 22.

from left to right will emerge from E', parallel to the axis. We can, if we choose, geometrically construct our final picture of A B C on the same principle as was previously adopted for a single lens. From A draw a ray to the first equivalent point A E, this will emerge from E' in a direction parallel to A E. From A draw a ray to the first equivalent plane A*m* parallel to the axis, this will emerge from a point *n* on the second equivalent plane; the distance E'*n* being equal to E*m*. But the ray A*m* is parallel to the axis, and we know that the second focus F' is that point on the axis through which all light parallel to the axis passes, thus the ray A*m*, after passing through the microscope must emerge through the point F' and the point I where these two rays meet, indicate the position where the virtual image I J K of the object A B C is formed by means of the microscope.

The microscope gives one the impression that it is a lens turned inside out. In a lens, the surfaces of the lenses, the object, the eye, and the two foci are outside, and the two equivalent planes from which all the refraction appears to take place are inside; whereas, as in the case of a compound microscope, these equivalent planes are outside, and the object, the eye of the observer, the two foci, and all the lenses composing the instrument are between them.

When it is remembered that the microscope is used with such a variety of different eyepieces and object glasses in the course of even one investigation, it becomes obvious that it is more convenient to treat it as a combination of two optical systems than as one. From a purely optical standpoint, however, it is interesting to note that the above exhibits it as a most curious instrument.

My object in this article has been to present to the microscopist a simple explanation of the general optical laws upon which vision through a microscope depends. One most important question has merely been alluded to, namely, The Theory of Aperture. It would be impossible, however, with such limited space, to discuss so large a subject. The methods employed by the optician to make the many corrections requisite to produce a good microscope, and the explanation of the principles upon which the different lenses are arranged have not been attempted. All I have wished to achieve will have been accomplished, if the method which I have employed in dealing with this optical problem, proves to be of assistance to any who have hitherto been puzzled by the necessarily condensed form in which this portion of microscopical theory generally appears in the textbooks.

MATHEMATICAL APPENDIX.—For the complete elucidation of optical problems by means of the Gauss system, mathematical proofs are necessary, but these may be of a simple character, and if presented after the plan adopted by Dr. Ferraris, of Turin, algebra and a slight acquaintance with trigonometry are sufficient for the full mastery of the subject.

An explanation of the Gauss system by means of elementary mathematics has not as far as I am aware appeared in the English language, and I am therefore not without hope that an algebraical proof, although owing to the space at my command it must be in a condensed form, may be of service to students not only on microscopical matters, but as applied to all elementary refracting instruments.

The method of considering directions as positive or negative according to whether they are measured to the right or left of the known point as explained in the first part of this article, will be adhered to. All lenses and combinations of lenses will be considered as "centred" systems, that is to say, it will be assumed that the centres of all curved surfaces lie on one and the same straight line, termed the axis of the system. It must always be remembered when applying the Gauss system to *uncorrected* lenses that the theory is only true for rays close to the axis, and at small obliquity to the same. To build up the theory we must assume a further property of light—the law of refraction—which has been proved by experiment to be correct. It states that when a ray of light passes from one medium into another the amount of bending or refraction that takes place is dependent not directly upon the angle which the light makes with the normal to the surface, but upon the sine of that angle. That is to say, in fig. 1 :

$$\frac{\text{Sin (Angle of Incidence)}}{\text{Sin (Angle of Refraction}} \text{ or } \frac{\text{Sin BOO'}}{\text{Sin B'O,O''}} = \frac{\mu'}{\mu}$$

where μ' represents the refracting power, or refractive index as it is termed, of the second medium, and μ that of the first. For practical work, the refractive index of air is considered to be 1, although strictly it is a vacuum that has a refraction of unity. The refractive index of air is so slightly above that of a vacuum that it need not concern us and the law of refraction, when the first medium is air and $\mu = 1$, becomes—

$$\frac{\text{Sin (Angle of Incidence)}}{\text{Sin (Angle of Refraction)}} = \mu'$$

indeed this is the way in which it is often expressed. The first method is, however, the better one, as it is universally true whatever the refractive indices of the two media.

The further property of this law of refraction that has been proved by experiment is that the incident and refracted rays always lie in the same plane, as for instance the plane of the paper. The propositions contained in this article

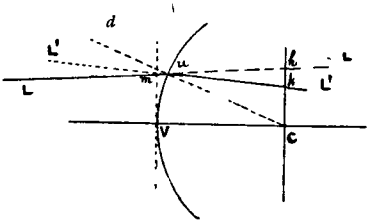

Fig. 23.

will only deal with light in one plane, namely, that of the paper; it is obvious that as all the curves are supposed to be spherical, and as we are not dealing with oblique pencils, any problem connected with a point not included in the plane of the paper may be solved by supposing this point and the optical apparatus to be rotated on the axis of the system until such point lies in the plane of the paper.

SYSTEMS OF TWO MEDIA ONLY, SEPARATED BY A CURVED SURFACE.—

Proposition 1—

Let fig. 23 represent such a system with the separating surface cutting the axis at V, whose centre of curvature lies at C, thus VC = r = radius of curvature. Let μ be refractive index of 1st or left-hand medium, and μ' be refractive index of right-hand or second medium.

L L = Incident ray. C u = normal to surface at u.

L' L' = Refracted ray. Angle of Incidence = $d\,u$ L = C u h.

Angle of Refraction = C u K.

$$\frac{\text{Sin C}\,u\,h}{\text{Sin C}u\text{K}} = \frac{\mu'}{\mu}$$

Our theory deals only with rays almost parallel to the axis, in which case the angles $c\,h\,u$ and $c\,k\,u$ may both be considered to be almost equal to right angles, and

$$\text{Sin } c\,u\,h = \frac{c\,h}{c\,u} \text{ also Sin } c\,u\,k = \frac{c\,k}{c\,u}$$

and

$$\frac{\text{Sin } c\,u\,h}{\text{Sin } c\,u\,k} = \frac{c\,h}{c\,k}$$

or

$$\frac{c\,h}{c\,k} = \frac{\mu'}{\mu}$$

Also as we are dealing only with rays close to the axis, the surface may be represented by its tangent, and we may consider that u coincides with m.

Therefore: *An incident ray continued cuts a plane at right angles to the axis, situated at the centre of curvature, at a distance from the axis in the proportion of the refractive indices* $\frac{\mu'}{\mu}$ *to the distance at which its refracted ray cuts this plane.*

Proposition 2:

Let V (fig. 24) represent a surface separating two media with a centre C. Let L m A be the course of an incident ray refracted in the direction m K B, and let m'' C A be a ray incident towards the centre of curvature C. This will

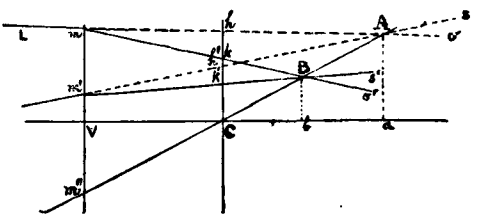

Fig. 24.

obviously pass through without refraction because it meets the surface at right angles to the point of impact. Take any ray m' A and join the point m' to B. If we can prove that the line m' B is the course of the incident ray m' A after refraction we shall show that any ray passing through the point A will be refracted to B, because this ray m' A might be chosen in any other position without affecting the proof.

To prove this we must show that

$$\frac{C\,h'}{C\,k'} = \frac{C\,h}{C\,k} = \frac{\mu'}{\mu}$$

In the triangle, m A m'', h A C and m B m'', k B C—

$$\frac{C\,h}{m\,m''} = \frac{C\,A}{m''\,A} \quad \text{and} \quad \frac{C\,k}{m\,m''} = \frac{C\,B}{m''\,B}$$

or dividing the two equations,

$$\frac{C\,h}{C\,k} = \frac{C\,A,\ m''\,B}{C\,B,\ m''\,A}$$

In the triangle, m' A m'', h' A C and m' B m'', k' B C—

$$\frac{C\,h'}{m'\,m''} = \frac{C\,A}{m''\,A} \quad \text{and} \quad \frac{C\,k'}{m'\,m''} \quad \frac{C\,B}{m''\,B}$$

or dividing these equations,

$$\frac{C\,h'}{C\,h'} = \frac{C\,A,\ m''\,B}{C\,B,\ m''\,A}$$

$$\therefore \quad \frac{C\,h'}{C\,k'} = \frac{C\,h}{C\,k}$$

Therefore if $\frac{C\,h'}{C\,k'} = \frac{C\,h}{C\,k}$ which latter is by construction equal to $\frac{\mu'}{\mu}$ m' B must be the refracted ray corresponding to the incident ray m' A.

Thus as the position of the ray m'A was taken at random it is proved

That all Incident Rays, passing through one point, will after Refraction pass through another point, such points are said to be *Conjugate* to each other. *Each pair of Conjugate points lie on one straight line passing through the centre of curvature.*

Proposition 3. In fig. 24 Let $Va = x$, $Vb = x'$, $VC = r$

For rays at small obliquities to the axis

$$m''B = x', \quad m''A = x, \quad m''c = r$$

In the triangles $m''Am$, CAh

$$\frac{AC}{Am''} \text{ or } \frac{x-r}{x} = \frac{Ch}{m''m}$$

In the triangles $m''Bm$, k B C

$$\frac{BC}{Bm''} \text{ or } \frac{x'-r}{x'} = \frac{Ck}{mm''}$$

dividing the Equations

$$\frac{\dfrac{x-r}{x}}{\dfrac{x'-r}{x'}} = \frac{Ch}{Ck}$$

but $$\frac{Ch}{Ck} = \frac{\mu'}{\mu} \quad \left(\text{Prop. } 1\right)$$

$$\therefore \quad \frac{x'-r}{x'} = \frac{\mu}{\mu'} \frac{x-r}{x} \quad (d)$$

This may be written $\mu' x x' - \mu' x r = \mu x' x - \mu x' r$ dividing by $x x' r$

$$\frac{\mu'}{r} - \frac{\mu'}{x'} = \frac{\mu}{r} - \frac{\mu}{x}$$

or $$\frac{\mu'}{x'} - \frac{\mu}{x} = \frac{\mu'-\mu}{r} \quad (1)$$

If in fig. 24 $Aa = y$ and $Bb = y'$

$$\frac{y}{y'} = \frac{x-r}{x'-r}$$

Inserting above in (d)

$$\frac{y}{y'} = \frac{\mu' x}{\mu x'} = 1 + \frac{\mu'-\mu}{\mu r} x \quad (2)$$

The latter portion of formula 2 is obtained by multiplying Equation 1 by $\frac{x}{\mu}$

Equation 1 shows that x is not dependant on the value of y, and proves

That all points in a plane at right angles to the axis have their conjugate points in another plane also at right angles to the axis. Such planes are called *Conjugate Planes.*

Equation 2 shows that the ratio $\frac{y}{y'}$ is independent of the absolute value of y, and that *the relative distance of conjugate points from the axis is only dependent upon the position of their conjugate planes.*

Proposition 4.

In the triangles A $m\ m'$, B $m\ m'$ (Fig. 24)

$$\text{Sin } \sigma \text{ A } s = \frac{m\ m'}{m'\ \text{A}} \text{ Sin A } m\ m'$$

$$\text{Sin } \sigma' \text{ B } s' = \frac{m\ m'}{m'\ \text{B}} \text{ Sin B } m\ m'$$

Also

$$m'\ \text{A} = \frac{\text{V } a}{\text{Sin A } m'\ m} = \frac{x}{\text{Sin A } m'\ m}$$

$$m'\ \text{B} = \frac{\text{V } b}{\text{Sin B } m'\ m} = \frac{x'}{\text{Sin B } m'\ m}$$

$$\text{Sin } \sigma \text{ A } s = \frac{m\,m'}{x} \text{ Sin A } m\ m' \text{ Sin A } m'\ m$$

$$\text{Sin } \sigma' \text{ B } s' = \frac{m\,m'}{x'} \text{ Sin B } m\ m' \text{ Sin B } m'\ m$$

For light at small obliquity the angles A $m\ m'$, A $m'\ m$ and B $m\ m'$, B $m'\ m$ may be considered to be so nearly right angles that their signs may be considered to be equal to unity and

$$\text{Sin } \sigma \text{ A } s = \frac{m\,m'}{x} \qquad \text{Sin } \sigma' \text{ B } s' = \frac{m\,m'}{x'}$$

We may also for these small angles consider the sines equal to the angles, and if we call $< \sigma$ A $s = \omega$ and σ' B $s' = \omega'$

$$\frac{\omega}{\omega'} = \frac{x'}{x} \quad (3')$$

and from equation 2 Prop. 3 $\quad \dfrac{y}{y'} = \dfrac{\mu' x}{\mu x'}$

$$\therefore \quad \frac{\omega}{\omega'} = \frac{\mu' y'}{\mu y} \quad (3)$$

From Equation (3′) we see that

The ratio between the angle subtended by two incident rays passing through a point and the angle subtended by their two refracted rays passing through the conjugate point is dependent upon the position of the conjugate planes, and not upon the position of the points in these planes.

Definition of Focus.—If one of the two conjugate planes be situated at infinity the other is called the *Focal plane*, and the point where this plane cuts the axis the Principal Focus or *Focus*. It is obvious that there are two focal planes and foci as it is possible to place a plane at infinity on the right hand or to the left of our optical system. To distinguish these, the two focal planes and foci, they are called first and second according to the following definition.

If a plane be situated at infinity upon the right-hand side of our optical system its conjugate plane is termed the First Focal Plane *and the point where this plane cuts the axis is the* First Focus. *If a plane be situated at infinity upon the left-hand of the optical system its conjugate plane is termed the* Second Focal Plane, *and the point where this plane cuts the axis the* Second Focus. We shall call the distance of the first focus from the refracting surface f and that of the second focus f'.

Proposition 5:

If we examine equation (1), Proposition 3, we shall immediately obtain the values for f and f'. If we make $x' = \infty$ $x = f$, and if we make $x = \infty$ $x' = f'$ and the equation becomes

$$f = -\frac{\mu r}{\mu' - \mu} \qquad f' = \frac{\mu' r}{\mu' - \mu} \quad (4)$$

This proves that the two focal distances have always different signs, and therefore always lie upon different sides of the refracting surface. If the *second focal* distance be a *positive* or plus quantity the optical system is termed a *positive* or convergent system. If the *second* focal distance be a negative or minus quantity the optical system is termed a *negative* or divergent system. Thus the position of the *second* focus gives the name to the optical system; it lies to the right of a positive and the left of a negative system.

SYSTEMS OF ANY NUMBER OF MEDIA.—Certain propositions which we have proved to be true for systems of two media only are also true for those of any number of media. Their nature is such as to render it obvious that being true for media Nos. 1 and 2, for Nos. 2 and 3, or Nos. 3 and 4, they will also be true for the first and last media Nos. 1 and 4. For instance if light from a point in medium No. 1 comes exactly to a point in medium No. 2, and light from this point in medium No. 2 comes exactly to another point in medium No. 3, then it is evident that light from a point in the first medium will come to an exact point in the last medium, however many of such media there may be.

The propositions which being true for two media, are obviously true for any number are the following.

Proposition 6. *All incident rays in the first medium, passing throngh one point, will after refraction into the last medium pass through one point. Such points are called conjugate points.*

Proposition 7. *All points in a plane at right angles to the axis after refraction through any number of media have their conjugate points in a plane at right angles to the axis. Such planes are called conjugate planes. The relative positions of a pair of conjugate points in their conjugate planes is independent of their absolute position in those planes.*

Proposition 8. *In systems of any number of media, the ratio between the angle of two incident rays passing through a point and that of their two final emergent rays is independent of the distance of the point from the axis of the system.*

It will be convenient to call the refractive index of the 1st, 2nd, 3rd, 4th, etc., and last media. μ, μ_1, μ_2, μ_3, μ_4, μ', and the same method will be adopted with x and y.

Proposition 9. Let fig. 25 represent an optical system of some kind with its axis XX', it is drawn as a lens with two surfaces, but it would make no difference to the argument if it were a number of lenses. All that we require is that it should be a system possessing two focal points.

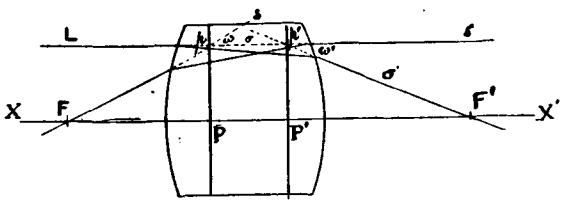

Fig. 25.

Let us suppose that the two focal points are at F and F'. Take any parallel ray of light L s' travelling from left to right. We know that this ray upon emergence from the system will pass through F', we do not know in what

direction it will proceed, but if it were to proceed in the direction σ' F', which in the form of lens drawn would be the case, the continuation of the emergent ray σ' F' would cut the continuation of the incident ray L p at p'. If the lens system had other characteristics than the one in fig. 25 it might proceed in some other direction, and the point where the emergent and incident rays met might be in some other position, but there would always be a point of intersection.

Now let us consider the ray $s'p'$ parallel to the axis incident from right to left, this ray will emerge through the focus F, and there must be a point of intersection of this incident and its emergent ray. In fig. 25 this point is at p. Therefore p is a point through which a ray L p or its continuation passes, which emerges as the ray p' F', and through which the ray F s or its continuation passes, emerging as the ray $p's'$. That is to say, two rays of light incident to the point p emerge from the point p' and thus by Prop. 6 p and p' are conjugate points, and all rays incident on p will emerge from p'. If the optical system be of a different nature to that shown in fig. 25, the position of p and p' might be different, but as long as an optical system has foci these points will exist. It is also evident as the ray L s' is parallel to the axis $x\,x'$ that the distance of p from the axis is equal to the distance of p'. From Prop. 7 we see that if two planes p P and p' P' be drawn at right angles to the axis these planes will be conjugate planes.

The planes p P and p' P' are called *Principal Planes* and the points P P' where they cut the axis are called *Principal points*. In fig. 25 the same argument would apply whatever distance from the axis the straight line L s' be taken, and therefore a line parallel to the axis always cuts the two principal planes at two conjugate points.

It is therefore proved

That in every refracting system that possesses a focus there are two conjugate planes termed principal planes, in which any point on the first principal plane has its conjugate point on the second principal plane at an equal distance from the axis of the system

$$\text{or } \frac{y}{y'} = 1$$

The two principal planes are called first and second. If light be travelling from left to right the *first principal plane* will contain points towards which *incident* rays travel, and the *second principal plane* will contain their conjugate points from which *emergent* rays proceed or appear to proceed.

In systems of two media the focal distance represents the distance from the focus to the refracting surface, but in systems of any number of media the *focal distance* is the distance P F of the first focus from the first principal point, or the distance P' F' of the second focus from the second principal point. Thus

$$-\text{P F} = f \quad \text{and} \quad \text{P' F'} = f'$$

Proposition 10. In Proposition 4 we say that for the first and second media

$$\frac{\omega}{\omega_1} = \frac{\mu_1}{\mu}\frac{y_1}{y}$$

for the second and third media

$$\frac{\omega_1}{\omega_2} = \frac{\mu_2}{\mu_1}\frac{y_2}{y'}$$

for the third and fourth media

$$\frac{\omega_2}{\omega'} = \frac{\mu'}{\mu_2}\frac{y'}{y_2}$$

By multiplying these formulæ together we obtain

$$\frac{\omega}{\omega'} = \frac{\mu'}{\mu}\frac{y'}{y}$$

In the particular case where ω and ω' are measures of the angle of light passing through a pair of conjugate points in the principal planes as $p\,p'$, fig. 25, where

$$\frac{y'}{y} = 1$$

for points in these planes

$$\frac{\omega}{\omega'} = \frac{\mu'}{\mu}$$

If the angles ω and ω' are small, as it is assumed in this theory is the case, the angles are almost equal to their tangents and

$$\frac{\tan.\ \omega}{\tan\ \omega'} = \frac{\mu'}{\mu}$$

but

$$\tan.\ \omega = \frac{P\,p}{P\,F} \quad \text{and} \quad \tan.\ \omega' = \frac{P\,p}{P'\,F'}$$

$$\therefore \frac{P\,F}{P'\,F'} = \frac{\mu'}{\mu}$$

$$\text{or} \quad \frac{f}{f'} = -\frac{\mu'}{\mu}$$

This proves that in systems of any number of media

The two focal distances of any optical system have always different signs and that the ratio of the first focal distance to that of the second is equal to that of the refractive indices of the last and first media.

Proposition 11—

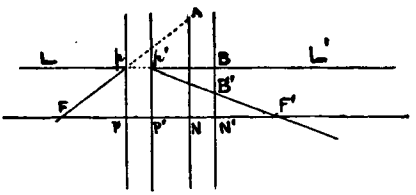

Fig. 26.

Let us take an optical system (fig. 26) as in fig. 25, in which P p P′p' are the principal planes and F F′ the foci. Let us suppose N A and N′B to be a pair of conjugate planes. Then the point A is evidently a conjugate point to B because the ray passing through the first focus F meets the plane N A at A; and this ray will emerge in the direction $p p'$ B, meeting the plane N′B conjugate to N A at B for these points.

$$\frac{y'}{y} = \frac{N'B}{N\,A} = \frac{P\,p}{N\,\backslash}$$

but from (Prop. 10),

$$\frac{\omega}{\omega'} = \frac{\mu'}{\mu}\quad\frac{y'}{y}$$

therefore

$$\frac{\omega}{\omega'} = \frac{\mu'}{\mu}\quad\frac{P\,p}{N\,A}$$

Now if we place the pair of conjugate planes in such a position that

$$\frac{y}{y'} \text{ or } \frac{N\,A}{P\,p} = \frac{\mu'}{\mu}$$

then $\frac{\omega}{\omega'} = 1$ or $\omega = \omega'$.

This proves that

There are a pair of Planes in any optical system which we call NODAL PLANES, *which possess the property that the angle of two rays incident through any point in one plane will be equal to the angle made by the same rays when emergent through its conjugate point in the other.*

The points where these planes cut the axis are called the *Nodal Points.*

From this it will be apparent that if one of the rays forming the angle ω be the axis of the system, any ray incident to the 1st nodal point will emerge from the 2nd nodal point in a direction parallel to its incident ray.

Proposition 12.—It is evident that in the planes N A, N′ B (fig. 26), B′ is conjugate to A′, as well as B conjugate to A, and when these planes are in the position of the nodal planes

$$\frac{y}{y'} = \frac{\mu'}{\mu} \therefore \frac{N'\,B'}{P'\,p'} = \frac{\mu}{\mu'} \text{ and } \frac{N\,A}{P\,p} = \frac{\mu'}{\mu}$$

But in the similar triangle, F N A, F p P and F′ p' P′, and F′ N′ B′—

$$F\,N = F\,P\,\frac{N\,A}{P\,p} \qquad F'\,N' = F'\,P'\,\frac{N'\,B'}{P'\,p'}$$

$$\therefore\ F\,N = F\,P\,\frac{\mu'}{\mu} \qquad F'\,N' = F'\,P'\,\frac{\mu}{\mu'}$$

But $-$ F P $= f$ and P′ F′ $= f'$

$$\therefore \quad \text{F N} = -f\frac{\mu'}{\iota} \text{ and } \text{F}'\text{ N}' = f\frac{\mu}{\mu'}$$

But in proposition 10 we proved that

$$\frac{f}{f'} = -\frac{\mu'}{\mu}$$

$$\therefore \quad \text{F N} = f' \text{ and } -\text{F}'\text{ N}' = f.$$

Which proves that

The First Nodal Plane lies at a distance from the First Focal point equal to the second focus, and the Second Nodal Plane lies at a distance from the Second Focal point equal to the first focus.

We see, therefore, that in any optical system there are six important points—two foci, two principal points, and two nodal points. These are called the *Fundamental points* of a refracting system.

Let us now see how the position of these fundamental points can be obtained in systems of any number of media. As space is limited, I propose first of all to show how they can be calculated in a lens consisting of two surfaces and three media, the first and last of which are air, and afterwards to prove how they may be calculated for two lenses with an air space between. In this manner a further combination of lenses may be calculated by considering the first two lenses as one, and completing the problem with a third lens; again the three being reckoned as one, a fourth lens may be added, and so on.

The first point to be considered is, that if the first and last media are air, the two focal distances are equal in length though opposite in sign, for we know that

$$\frac{f}{f'} = -\frac{\mu'}{\mu}$$

but μ' and μ are in this case both 1,

$$\therefore \quad f = -f'.$$

The focal distance of an optical system with air on either side will be always denoted by ϕ, and its sign always follows the sign of the second focus, as defined on page 132—i.e., if the plane conjugate to an object at an infinite distance to the left, is *positive*, or on the right-hand side of the second principal plane, the focus of the lens is positive and *vice versa.*

It will also be observed that when the first and last media are air, the position of the nodal points is identical with that of the principal points, because the position of the nodal points is given by the equation,

$$\text{F N} = f' \text{ and } \text{F}'\text{ N}' = -f$$

and we know that in this case $f' = -f = \phi$, therefore N and N′ coincide with P and P′.

I call the superimposed principal and nodal planes *The Equivalent Planes.*

Proposition 13—

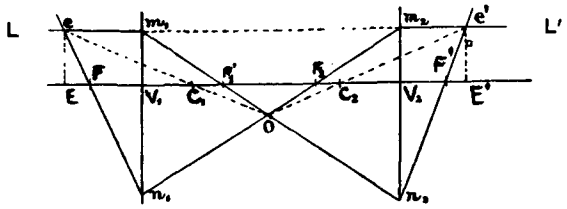

Fig. 27.

Let n_1 V_1 m_1 (fig. 27) represent one refracting suface with centre C_1, and let n_2 V_2 m_2 represent a second surface with centre C_2. Let F_1 F'_1 be the foci of the first surface, and F_2 F'_2 those of the second surface. Let L L' be a ray parallel to the axis E E'. The ray L *e* after passing through the first surface will be refracted through F'_1, meeting the second surface at n_2. The ray L' *e'* proceeding in the opposite direction will be refracted at the surface V_2 m_2 through F_2 to n_1. The point O where these rays cross will obviously be a conjugate point to both the points when the line L L_1 cuts the equivalent planes. This is evident because the ray L' m_2 O n_1 *e* will pass through the point *e* on the first equivalent plane, and also the ray n_2 O m_1 *e* will pass through this point *e* (compare proposition 9), therefore wherever the point *e* happens to be, we know that the point O is conjugate to it, and that all rays passing through O will also pass through *e* and *vice versa*. The same argument applies to the point *e'*. Therefore if we draw the lines O C_1, O C_2, which will pass through their respective surfaces, of which C_1 and C_2 are the centres, without refraction, the point where they cut the ray L L_1 will give us the positions of the equivalent planes E *e* and E' *e'*, and by joining up the lines n_1 *e* and n_2 *e'* the courses of the emergent rays corresponding to the incident rays L' m_2 and L m_1 will be given, and the points F and F' where n_1 *e* and n_2 *e'* cut the axis will be the focal points of the entire system.

In the triangles m_1 O m_2, F'_1 O F_2 and m_2 O *e'*, F_2 O C_2

$$\frac{m_2\ e'}{m_1\ m_2} = \frac{C_2\ F'_2}{F'_1\ F_2} \quad (d)$$

In the triangles E' *e'* F', *e'* m_2 n_2

$$\frac{E'\ F'}{e'\ m_2} = \frac{E'\ e'}{m_2\ n_2} = \frac{m_1\ V_1}{m_2\ n_2}$$

In the triangles m_1 V_1 F'_1, m_1 n_2 m_2

$$\frac{m_1\ V_1}{m_2\ n_2} = \frac{V_1\ F'_1}{m_1\ m_2}$$

$$E'\ F' = \frac{V_1\ F'_1 \times e'\ m_2}{m\ m_2}$$

Or inserting from (*d*) $E'\ F' = \dfrac{V_1\ F'_1 \times C_2\ F_2}{F'_1\ F_2}$

We prove that for two media only

$$f = -\frac{\mu r}{\mu' - \mu} \text{ and } f' = \frac{\mu' r}{\mu' - \mu}$$

therefore $f + f' = r$

or $f' = r - f$

$V_1 F_1' = f_1'$ and $E' F' = \phi C_2 F_2 = r_2 - f_2 = f'_2$ and if we call the distance $V_1 V_2$ or the thickness of our lens Δ

$$F'_1 F_2 = \Delta + f_2 - f'_1$$

$$\phi = \frac{f'_1 f'_2}{\Delta + f_2 - f'_1}$$

From equation (*d*)—

$$V_2 E' = \frac{\Delta f'_2}{\Delta + f_2 - f'_1}$$

Similar reasoning gives—

$$V_1 E = \frac{\Delta f_1}{\Delta + f_2 - f'_1}$$

This gives the positions of the principal planes and the focus of the lens in terms of the foci of the individual surfaces, and in order to obtain them in terms of the curves of the lens, we have merely to insert the values of the foci from the equations $f = -\frac{\mu r}{\mu' - \mu}$ and $f' = \frac{\mu' r}{\mu' - \mu}$ remembering that in the first surface μ is 1, and that in the second surface μ' is 1, and we obtain the universal formulæ for a lens.

$$\phi = \frac{r r'}{(\mu - 1)\left[r' - r + \frac{\mu - 1}{\mu}\Delta\right]}$$

$$V E = -\frac{r \Delta}{\mu \left[r' - r + \frac{\mu - 7}{\mu}\Delta\right]}$$

$$V' E' = -\frac{r' \Delta}{\mu \left[r' - r + \frac{\mu - 1}{\mu}\Delta\right]}$$

where μ is the refractive index of the glass or other material of which the lens is made.

In the case of infinitely thin lenses, where $\Delta = 0$, these formulæ become—

$$\frac{1}{\phi} = (\mu - 1)\left[\frac{1}{r} - \frac{1}{r'}\right]$$

$$V E = 0 \qquad V' E' = 0$$

In the case of a plano lens, where $r' = \infty$, the equations become—

$$\phi = \frac{r}{\mu - 1}$$

$$V E = 0$$

$$V' E' = -\frac{\Delta}{r}$$

Proposition 14.—The next point to be considered is the formulæ for obtaining the positions of the equivalent planes and the foci of a pair of lenses.

The argument is the same as that of Proposition 13, with the exception that the equivalent planes of the individual lenses take the place of the surfaces and centres of the single surfaces.

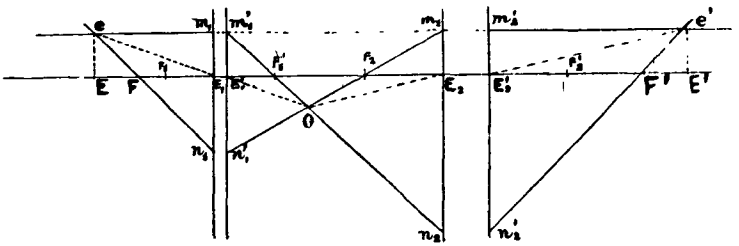

Fig. 28.

The geometrical construction is similar, except that the line $e\ C_1$ is replaced by the parallel lines $e\ E_1$ and $E_1'\ O$, and the line $e'\ C_2$ is replaced by the parallel lines $e'\ E_2'$ and $E_2\ O$; also the surfaces represented by lines in fig. 27 are replaced by the pair of equivalent planes belonging to each lens.

The proof of the formulæ is similar. Let the distance between the second equivalent plane of the first lens and the first equivalent plane of the second lens be denoted by Δ, let the foci be denoted by ϕ_1, ϕ_2 and ϕ, the distance $F_1'\ F_2$ will be in this case $\Delta - \phi_1 - \phi_2$. The signs of ϕ_1 and ϕ_2 (fig. 28) it will be noted are both positive as $E'_1\ F'_1$ and $E'_2\ F'_2$, the second foci of the lenses are in both cases measured from left to right, and our proof will become in the triangles $m'_2\ e'\ E'_2$, $m_2\ O\ E_2$, $F_2\ E_2\ O$ and $m'_1\ m_2\ O\ F'_1\ F_2\ O$.

$$\frac{m'_2\ e'}{\Delta} = \frac{\phi_2}{\Delta - \phi_1 - \phi_2}$$

$$m'_2\ e' = \frac{\Delta\ \phi_2}{\Delta - \phi_1 - \phi_2} \quad (d)$$

In the triangles $F'\ E'\ e'$, $e'\ m'_2\ n'_2$ and $m'_1\ E'_1\ F'_1$, $m'_1\ m_2\ n_2$

$$\frac{-\phi}{m'_2\ e'} = \frac{E'\ e'}{m'_2\ n'_2} = \frac{m'_1\ E'_1}{m'_2\ n'_2} = \frac{\phi_1}{\Delta}$$

$$-\phi = \frac{m'_2 e' \times \phi_1}{\Delta}$$

Insert value of $m'_2 e'$ from (d) and

$$\boxed{\phi = \frac{\phi_1 \phi_2}{\phi_1 + \phi_2 - \Delta}}$$

$$m'_2 e' = E'_2 E' = -\frac{\Delta \phi_2}{\phi_1 + \phi_2 - \Delta}$$

In a similar manner we prove that

$$E_1 E = \frac{\Delta \phi_1}{\phi_1 + \phi_2 - \Delta}$$

It will be well before concluding the mathematical work to prove the standard formulæ referring to conjugate images. If, as before, x and x' be the distance of the object and image respectively from the first and second equivalent planes and y and y' the height above the axis of any two conjugate points then in fig. 11

$$-A L = x \quad M' I = x' \quad A B = y \quad -I J = y'$$

In the similar triangles A L M, F E M,

$$-\frac{\phi}{x} = \frac{E M}{L M} \quad (a)$$

and in the similar triangles L' I M'; L' E' F'

$$\frac{\phi}{x'} = \frac{L' E'}{L' M'} \quad (b)$$

by adding the equation a and b

$$\frac{\phi}{x'} - \frac{\phi}{x} = \frac{E M + L' E'}{L M} = 1$$

$$\text{or} \quad \frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi} \quad (1)$$

Also in the similar triangles A E B, J E' I

$$\frac{y}{y'} = \frac{x}{x'} \quad (2)$$

by combining formulæ (1) and (2)

$$\frac{y}{y'} = 1 + \frac{x}{\phi} \qquad \frac{y'}{y} = 1 - \frac{x'}{\phi}$$

By means of these formulæ which are collected below most of the problems connected with the simple theory of lenses may be calculated. The student

interested in the question can readily work out the differences that will occur when the first and last media are not air.

Fundamental formulæ for dealing with lens systems by the method of Gauss.

Lenses.

$$(1)\quad \phi = \frac{r r'}{(\mu-1)\left[r' - r + \frac{\mu-1}{\mu}\Delta\right]}$$

$$(2)\quad V E = -\frac{r \Delta}{\mu\left[r' - r + \frac{\mu-1}{\mu}\Delta\right]}$$

$$(3)\quad V' E' = -\frac{r' \Delta}{\mu\left[r' - r + \frac{\mu-1}{\mu}\Delta\right]}$$

r = Radius of curvature of first surface of lens.

r' = Radius of curvature of second surface of lens.

ϕ = Focal distance or equivalent focus of lens measured from equivalent planes.

Δ = Distance between surfaces of lens on the axis.

μ = Refractive index of lens medium.

V E = Distance of first equivalent plane from first surface of lens.

V' E' = Distance of second equivalent plane from second surface of lens.

Thin Lenses.

$$(4)\quad \phi = (\mu - 1)\left[\frac{1}{r} - \frac{1}{r'}\right]$$

Two Lenses.

$$(5)\quad \phi = \frac{\phi_1 \phi_2}{\phi_1 + \phi_2 - \Delta}$$

$$(6)\quad E_1 E = \frac{\phi_1 \Delta}{\phi_1 + \phi_2 - \Delta}$$

$$(7)\quad E'_2 E' = -\frac{\phi_2 \Delta}{\phi_1 + \phi_2 - \Delta}$$

$\Delta = E'_1 E_2$ = Distance of second equivalent plane of first lens from first equivalent plane of second lens. Always considered positive when there is an interval between E'_1 and E_2, and negative where they overlap.

$E_1 E$ = Distance from first equivalent plane of first lens to first equivalent plane of whole system.

$E'_2 E'$ = Distance from second equivalent plane of second lens to second equivalent plane of whole system.

Conjugate images.

$$(8)\quad \frac{1}{x'} - \frac{1}{x} = \frac{1}{\phi}$$

$$(9)\quad \frac{y}{y'} = \frac{x}{x'}$$

$$(10)\quad \frac{y}{y'} = 1 + \frac{x}{\phi} \qquad \frac{y'}{y} = 1 - \frac{x'}{\phi}$$

x = Distance on the axis of object plane from first principal plane.

x' = Distance on the axis of image plane from second equivalent plane.

γ = Distance of object point from the axis.

γ' = Distance of image point from the axis.

Experimental means of ascertaining Fundamental Points in positive Lens systems.

To experimentally find the position of the fundamental points of a positive lens or lens system, we make use of the fact that every lens system will produce an image of an object situated at double the focal distance from the first equivalent plane, at a position double the focal distance from the second equivalent plane, and this image will be exactly the same size as the object. We may express it algebraically thus: if $x = -2\phi$, then from equation (8)

$$x' = 2\phi$$

and from equation (9) $\frac{y}{y'} = -1$ or $y = -y'$, the minus sign indicating that the image is inverted.

Fig. 29.

For large lenses or systems of lenses the apparatus required will be a ground glass screen and an object of a definite size, preferably an aperture, in a disc, the exact size of which must be marked on the ground glass. The optical system must be supported in such a manner that the ground glass and the disc may be moved towards and away from it so that the centre of each is always on the optic axis, and that each is at right angles to the axis. In fig. 29, let V be some portion of the lens system from which measurements can be made. Let the whole apparatus be now pointed towards a distant object, as, for instance, distant chimney tops. If the ground glass screen be now placed upon the opposite side of the lens to that of the distant object and moved to and fro. When it reaches the point F (fig. 29), a sharp image of the distant object will be observed on the screen. The distance V F of the screen from the fixed point on the lens should then be measured. This gives the position of the focus with reference to the point V on the lens, but does not give the focal distance. Now introduce the disc with the aperture upon the side of the lens opposite to the screen, and move both the disc and the ground glass about until a sharp picture of the aperture in the disc is formed by the lens upon the ground glass, of such a size that it exactly fits the shape previously marked upon the ground glass screen. This will show that the object and image are exactly the same size, and the object and screen will in this case be at S S'. Now measure the distance S V; then subtract V F from S V, and this is the focal distance of the system. The focal distance measured back from the point F will give the position of the first equivalent plane E. By making a second series of observations, only looking through in the opposite directions, the points F' and E' are obtained.

For short focus systems of lenses the microscope used with a low-power object glass is an excellent instrument for taking these measurements, the lens system being placed upon the stage of the microscope and adjusted so that it is central with the optic axis of the instrument. The light from a distant object should be thrown through the optical system by means of a *flat* mirror. The microscope body should be focussed up and down until a sharp image of the

distant object is obtained, and its position registered upon some fixed portion of the microscope stand. The microscope body should now be moved down till dust on the surface of the front lens of the optical system is in focus, and the amount that the body has been moved from its original position measured. This will give the distance F V (fig. 29); to obtain the distance S V, a micrometer with coarse rulings should be placed in the substage of the microscope, and the size that each division appears without the optical system which is being investigated should be recorded by means of an eyepiece micrometer. The optical system being now placed upon the stage of the microscope, the substage carrying the micrometer and the microscope body must be moved until they occupy such a position that the divisions of the micrometer below the stage appear to be of exactly the same size with reference to the eyepiece micrometer as was the case when the optical system was not under examination. The position of the microscope body may be again registered on any fixed portion of the microscope stand, and the amount of motion that is required to focus the dust on the front surface of the lens system will give the value of the distance S V.

By this means the fundamental points of most object glasses and eyepieces in general use may be readily obtained, and when these points have been found the investigation of all elementary problems connected with the microscope may be solved on the lines described in this article.

MULTIPLE IMAGES IN THE CORNEA OF A BEETLE'S EYE.

IN a large number of text-books on the microscope it is stated that if the cornea of a beetle's eye be placed on the stage of a microscope, and an object be placed between the source of illumination and the cornea, that object will be seen reproduced in every facet of the cornea. The experiment is an exceedingly interesting one, but there are very few people who know how it should be carried out. The cornea must be flattened, not left in the globular condition of life. The simplest way to exhibit the effect is to cut a cross out of brown paper, about $\frac{3}{4}''$ long, place this on the mirror of the microscope and focus the facets of the cornea in the usual way with a $\frac{1}{2}''$ objective. You then—and this is the important stage on which the result depends—gently rack the objective upwards, causing the structure to appear to go out of focus, at the

same time moving the cross on the mirror by means of a pointed stick of wood. It will be evident when it is best to stop raising the objective, for the cross or the stick will be seen in the facets. It then only remains for the cross to be so set on the mirror that it appears in the centre of each of the facets. There are many other ways in which the effect can be produced, a very pretty one being to throw a brilliant light on the face of a friend who sits at the side of the microscope, and so arranging the mirror that the reflection of his face falls upon it and is again transmitted to the cornea. Also by a little scheming the second hand of a watch can be seen in each of the facets. When well shown, these experiments always create astonishment and interest. A little practice soon enables one to do them with facility.

LIVING ACARI ARTIFICIALLY PRODUCED. IS IT A FACT?

WHILE reading a book* some few years ago, I met with a statement that some living insects had *seemed* to have been produced by artificial means. The statement was as follows:—

"A gentleman, named Crosse, was pursuing some experiments in crystallisation, causing a powerful voltaic battery to operate upon a saturated solution of silicate of potash, when the insects unexpectedly made their appearance. He afterwards tried nitrate of copper, which is a deadly poison, and from that fluid also did live insects emerge. The experiments were some years after pursued by Mr. Weekes, of Sandwich, with precisely the same results. This gentleman, besides trying the first of the above substances, employed ferro-cyanet of potash, on account of its containing a larger proportion of carbon, the principal element of organic bodies, and from this substance the insects were produced *in increased numbers*. A few weeks sufficed for this experiment with the powerful battery of Mr. Crosse, but the first attempts of Mr. Weekes required about eleven months, a ground of presumption in itself that the electricity was chiefly concerned in the phenomenon. The changes undergone by the fluid operated upon, were in both cases remarkable and nearly alike. In Mr. Weekes' apparatus, the silicate of potash became first turbid, then of a milky appearance; round the negative wire of the battery dipped into the fluid, there gathered a quantity of *gelatinous matter*, a part of the process of considerable importance, considering

* "Vestiges of the Natural History of Creation." Morley's Universal Library.

that gelatin is one of the *proximate principles*, or first compounds of which animal bodies are formed. From this matter Mr. Weekes observed one of the insects in the very act of emerging, immediately after which, it ascended to the surface of the fluid and sought concealment in an obscure corner of the apparatus. The insects produced by both experimentalists seem to have been the same, a species of acarus, minute and semi-transparent, and furnished with long bristles, which can only be seen by the aid of the microscope. It is worthy of remark, that some of these insects, soon after their existence had commenced, were found to be likely to extend their species. They were sometimes observed to go back to the fluid to feed, and sometimes they devoured each other."

From time to time I have made enquiries in the hope of ascertaining whether any of these acari have been preserved, or if anything is known concerning them, but unsuccessfully. It has occurred to me to mention the matter in the Annual, in the first place, because it is somewhat interesting, and secondly, in the hope that some reader might be able to impart some information on the subject. There is no doubt whatever, in my mind, that the matter may be explained in a scientific manner, and if it were at all possible to obtain a sight of the creatures, confirmation could at once be obtained, and so set at rest the ideas of any that might have been disturbed by a statement so contrary to the usually accepted ideas on the subject.

UNIFORMITY AND ACCURACY.

By M. I. Cross.

TO the working microscopist it is a great advantage, amounting almost to a necessity, that the objectives produced by the different makers shall interchange in the nosepiece of his microscope; but many of us have found that it has been impossible to screw home some objectives we have obtained until the thread has been eased, and have at once cast blame on the manufacturer. He, however, has not hitherto been altogether at fault, for no doubt he has worked to his standard gauges supplied by the Royal Microscopical Society many years ago, and is entitled to aver that his lenses are screwed to the "universal" thread and that others must be wrong.

Now this "universal" thread has for years been a misnomer, the gauges issued by the society having been slightly variable, and admittedly imperfect.

Recognising the desirability of establishing once for all a standard size, the society recently placed at the disposal of opticians and others who might wish to become possessed of such tools, accurately adjusted steel screw gauges. These

are so constructed as not to interfere "with the interchangeability of previous object glasses and microscope nosepieces which have been *correctly* made to the original standard," but by means of minute changes in the diameter "a slightly larger margin for error in individual lenses" is allowed for.

Microscopists would imagine that opticians would have gladly made use of a means which would have enabled their clients to derive so much convenience and benefit, but on enquiry it will be found that so far from this being the case, nothing has been done to give practical effect to the recommendations of the society, while the firm which is noted for using the most abnormal "universal" thread has shown no inclination whatever to work to the new gauge. The committee appointed last year to consider the question of this gauge was composed of as practical a set of men as could be selected for the purpose, yet from want of action on the part of manufacturers, the effort of the society seems likely to be a futile one. Wake up, opticians! do all you can to help those who pay your dividends—it will be profitable in the long run.

There are several other ways in which opticians could help microscopists. One matter is of first-rate importance, and that is the adoption of an universal size or sizes for eyepieces. This has been urged on many previous occasions, and here again it is the opticians who are at fault, for so long ago as the year 1882 the Royal Microscopical Society recommended the use of two sizes only, one with a diameter of fitting of 0·92 in. for students' instruments, and the other 1·35 in. for microscopes of large size. Who can say how many different gauges are used by the various manufacturers for eyepiece sizes? Yet the two sizes recommended would meet every want. The two features named above are much-needed reforms, and the only way in which they can be brought about is for workers to stipulate for the society's sizes and accept no other.

When these alterations have been effected there are plenty more matters that are worthy of attention, such as making the different eyepieces of a series to work in the same focal plane; having all eyepieces engraved with their initial magnifying powers rather than such absurd letters as A, B, C, etc. Then it would not be a practical impossibility for all the brass boxes in which object glasses are issued to be of uniform size or sizes, and for object glasses to be corrected to one definite thickness of cover glass, which would in addition permit of the correction collars of all objectives being divided alike, so that values should not have to be ascertained for each individual lens. If all these reforms were effected before another Annual were issued, many a microscopist would have been enabled to do better and more accurate work than hitherto. So much for uniformity, now for accuracy.

On testing an apochromatic object glass stated by the makers to have a numerical aperture of ·95, some months ago, I found that it was scarcely ·87. I returned it, and received an admission of the want of aperture, but notwithstanding long and weary waiting the firm—a very distinguished one—has not been able to produce a lens of the full aperture. This is a trivial matter compared with some I have examined where the over-statement has exceeded 20%. It must be admitted that a slight variation may occasionally occur, and in more

than one instance I have found an object glass to possess a larger aperture than that attributed to it. It is, however, an unfortunate fact that in the competition which has arisen in recent years to give large apertures at a moderate cost, makers have been so unscrupulous as to state the apertures of their objectives to be far in excess of that which they actually possess. This is fraud pure and simple, and it is a temptation which all opticians should have principle enough to withstand. Associated with this misrepresentation question is another of only slightly less importance; one is, in fact, the outcome of the other. Many objectives are stated to be of a certain focal power, but on testing, it will very frequently be found that they magnify considerably more than they should do. Thus a $\frac{1}{6}$ in., which should yield a magnification of 60 diameters at an image distance of ten inches, will probably prove to magnify about 70 diameters. It is obviously easier to give a larger aperture with an increased magnification in the objective, but it is no satisfaction to a worker to purchase an ostensible $\frac{1}{8}$ in. lens of, say, ·85 NA., to find that it is actually a $\frac{1}{7}$ in. of ·80 NA. or thereabouts. It is imperatively necessary that the powers and apertures of objectives be stated as nearly as possible.

Uniformity and accuracy are more than desirable in connection with the microscope, and the opinions expressed in this short note are those of a large section of working microscopists in all parts of the world.

AMATEUR BACTERIOLOGY.

Rev. William Spiers, M.A., F.G.S., F.R.M.S.,
Author of "Rambles and Reveries of a Naturalist," etc., etc.

MOST amateur microscopists are content to leave the study of bacteria to the experts. They suppose that special training and costly and elaborate apparatus are indispensable to real work of this kind. It is, of course, undeniable that for original research there is a necessity for some considerable knowledge of what has already been accomplished, and there must also be a fair proficiency in chemistry, physiology and the manipulation of instruments.

But even for those who have had no specific training, and whose lenses are not of the highest order, there is a wide available field for interesting and instructive work in bacteria. Anyone who has dealt *au sérieux* with, say, minute pond life, and possesses a tolerably good student's microscope, even such an one as Beck's "Star," with the attachments and lenses supplied for bacteriology, may do a good deal of useful work, and perhaps be led on ultimately to attempt higher flights.

It is for such as these that the present paper is written. Being based on actual experience, it is perhaps the more likely to be helpful to those who, as was the case with the author in years gone by, are dependent mainly on their own resources in their efforts to climb the steep hill of knowledge.

HISTORY OF BACTERIOLOGY.—It may not be amiss to say a word or two at the outset on the history of the subject. The existence of bacteria has been known ever since the days of Leeuwenhoek (1722) under one name or another, and Müller (1786) used such terms as monas, vibrio, bacillus and spirillum. Ehrenberg, Dujardin and some others, fifty or sixty years ago, gave attention to these minute organisms, but for want of good lenses were not able to accomplish very much. Schwann indicated the true nature of fermentation and decay, but his suggestion bore little fruit owing to the wrong theories of Liebig, which for some years led the world in the direction of error. Fuchs studied "blue milk," and Henle announced the supposition that there was some relation between disease and the growth of microscopic organisms. It was not, however, until 1866 that any satisfactory results were reached, when Louis Pasteur published his *Etudes sur le Vin*. This was followed by his works on vinegar and on beer. Then was demonstrated the causal connection of bacteria with fermentation and infectious diseases, and thus were laid the foundations of the modern science of bacteriology. Since that time progress has been rapid, and the literature of the subject has become bewilderingly prolific. Klein, Metschnikoff, Crookshank, Pfeiffer, Baumgarten, De Bary, Cohn, Sims Woodhead and a host of others have added their contributions to the ever-growing multitude of books, and Koch, more than any other save Pasteur, by his brilliant achievements in relation to tubercle and cholera, has helped to consolidate the now firmly-based and highly-developed science of which we write.

Those who wish for a fuller history of bacteriology and a detailed account of the successive stages by which it has come to be what it is, cannot do better than procure the admirable little book by H. W. Conn, entitled *The Story of Germ Life*, published by Newnes, or the rather larger volume on *Bacteria and their Products*, by Dr. Sims Woodhead, published by Walter Scott.

WHAT ARE BACTERIA ?—Bacteria are usually ranked in scientific classification as minute fungi. Like mushrooms and toadstools they are destitute of the colouring matter or chlorophyll, which is associated with the nutritive processes carried on in most plants, and derive their nutriment similarly to the great group of fungi. At the same time, there is so much in the development of bacteria that presents no affinities whatever with fungi that some careful microscopists prefer to place them in a separate and definite group at the base of the lowest fungi. The name *Schizomycetes*, by which they are scientifically known, means simply *fission-fungi*, and it indicates the method of their reproduction, namely, by fission or division. In this respect they are distinguished from the yeasts, which are propagated by a sort of budding. It must be stated, however, that many bacteria produce spores, which in some cases grow inside the organism (endogenous), in others they drop off from the breaking up of the rods (arthrogenous), while in yet other species they are poured out as a glairy mass. But we must not follow these intricate points into all their details.

Bacteria, then, may be considered as one-celled plants lying at the very bottom of the botanical scale. They live everywhere. In fluids of nearly all kinds they abound. No organism, living or dead, is entirely free from them. Even in inorganic materials they flourish and pervade our soils, but when found in the

air or among inorganic materials it would seem that there must be some organized substance present to afford them nutrition. They occur in all decaying structures, and in that natural incubator, the human mouth, there are generally at least half-a-dozen different kinds. It is fortunate that most of them are harmless, and that cleanliness and bodily health are a protection against even those which set up disease.

In size they vary from ·25μ to 1·5μ in diameter in the case of the spherical forms, while the rod-shaped are from ·3μ to 2μ in width; in English measurement from ·000012 to ·000096 inch.

They are of many different shapes—round, oval, spiral, cylindrical—as may be seen by glancing at the figures with which this article is illustrated. Many are motionless, while others are provided with flagella which keep up an incessant movement. They occur as separate organisms, in long threads and coils, and also in masses (zoöglœa) bound together by a gelatinous secretion. These varying appearances are of much importance in the determination and identification of species.

Classification.—Much confusion prevails in regard to the nomenclature and classification of bacteria. So far as genera are concerned, the shape of the organisms and their method of spore formation are sufficient guides, but when we come to deal with species we have to consider other points, such as colonies, diseases, oxidation and nitrification. With respect to generic names, however, there is substantial agreement, and these are not numerous. They are as follows:—

Micrococcus -	Seed-like or spherical forms.
Sarcina - - -	Cells bound together in definite numbers.
Bacterium - -	Short cylinders, single or united.
Bacillus - - -	Cylindrical cells joined together in threads.
Leptothrix - -	Very thin threads.
Beggiatoa - -	Threads somewhat thick.
Spirillum - -	Short spiral threads or vibriones.
Spirochæte - -	Long flexile threads.
Streptothrix - } Cladothrix - }	Threads with pseudo branches.
Myconostoc - -	Threads in gelatinous masses.

Non-Pathogenic Bacteria.—Although bacteria are usually associated in the popular mind with infectious disease, yet by far the greater number are non-pathogenic, indeed many are of great value in the arts, in manufactures, and in the preservation of health. As nature's scavengers they are of primary importance, and but for the services they render the world would soon become incapable of supporting life. In the manufacture of flax, jute, hemp and cocoa-nut fibre, in the cleansing of sponges from animal matter, in tobacco curing, in fermentation and the production of vinegar, in butter-making and the ripening of cheese, in maintaining the fertility of the soil, in the storing of hay by the silo process, and in other ways, these minute organisms fulfil most important functions, and it has

lately been shown that it is by their offices that the great food-cycle of nature is preserved intact, the nitrogen lost in the interchange of CO_2 and O, between animals and plants, being restored to the cycle by bacterial agency.

The typical organism of putrefaction used to be called *Bacterium termo* (fig. 1). This does not accurately represent the science of to-day, and *B. termo* is a somewhat indefinite term, but it will do for our present purpose. Swarms of these putrefactive organisms can be obtained in a few hours by the maceration of a few bits of chopped meat in warm water. Undeveloped monads will also exist in the

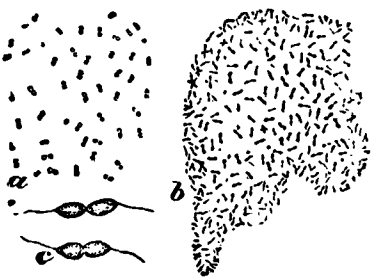

Fig. 1. Bacteria.

crowd, which in their immature condition cannot be distinguished from bacteria, but later on the monads will be larger and easily identified. For want of knowing this, some earlier observers thought they were warranted in saying that the bacteria developed into monads. As this was in opposition to the uniform law of nature that like produces like, other skilful microscopists, like Dr. W. H. Dallinger, gave careful attention to the subject. By examining separated forms and following continuously the whole life-cycle of the monads, the truth was at length established that bacteria produce only bacteria, and monads only monads.

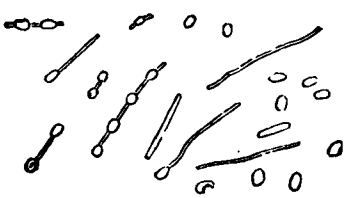

Fig. 2. Bacillus.

Thus was the false theory of Heterogenesis, as it is called, exploded. Abiogenesis or spontaneous generation arising from similar difficulties has been as completely vanquished.

Another very common non-pathogenic form, and one which is easy of observation, is *Bacillus subtilis* (fig. 2). It can be readily got by keeping a few wisps of hay for a day or two in water exposed to a moderate heat. This species furnishes a capital example of the rod-shaped forms, and also illustrates the growth of long filaments or chains.

Spirillum rugula (fig. 3) is shown as a representative of a large number of species of curved or spiral shape. It is common in bog-water, and occurs also in the slimy coating of the teeth.

Many other kinds of non-pathogenic bacteria can be obtained from different kinds of infusions, from milk, cheese, fruits and the soil.

PATHOGENIC BACTERIA.—Organisms associated with disease are perhaps not so attractive as those which have just been considered, but the investigation of them is of extreme consequence to mankind. Certain precautions are necessary in studying these, or serious results may ensue. The methods of sterilisation, the uses of germicides, and the proper modes of manipulating these dangerous

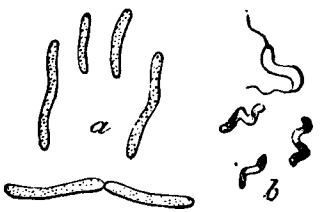

Fig. 3. Spirillum.

organisms, ought to be thoroughly understood before anything practical is attempted in the way of cultures. But all the commoner pathogenic species can be purchased ready prepared and mounted, and this would undoubtedly be the best step to take first. It is necessary to get a general idea of the forms themselves before thinking of growing them. Some of them are tolerably easy to identify, others are so similar in size and shape to non-pathogenic forms that only cultivation and chemical tests can lead to accurate results. Something further will be said presently on these points, meanwhile we will draw attention to a few of the commoner species.

Fig. 4. B. Tuberculosis.

At fig. 4 are represented a few chains of the organisms which are concerned in consumption or tubercle of the lung. As is known by everybody, it was Koch who discovered this bacillus, and he at once set himself to seek an antidote. After many disappointments he at length used for this purpose the products of the bacilli themselves dissolved in glycerine and water. This is an entirely different method from that which Pasteur followed in his treatment of disease. The great

French scientist inoculated with the virus itself after having weakened it by repeated cultivations; the German manufactured his *tuberculin* out of the *débris* caused by the ravages of the virus.

At fig. 5 are several other pathogenic forms:—

(*a*) *Micrococcus vaccinæ*, the bacterium of small-pox,

(*b*) *Micrococcus ureæ*, the ferment of urine.

(*c*) *M. ovatus*, associated with a silkworm disease.

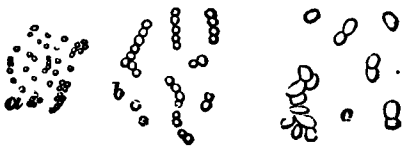

Fig. 5. Micrococci.

The virulent woolsorters' disease, which attacks both cattle and human beings, is always accompanied by rod-shaped microbes called *Bacillus anthracis* (fig. 6). The small oval bodies are spores, the development of which is indicated by the gradually increasing size of the figures. This is the organism that is found in swine fever, too well known to the farmer. The blood of infected animals is crowded with it, and it is well for man that the gastric juice has power to destroy this and similar organisms, for otherwise the human race would soon be exterminated.

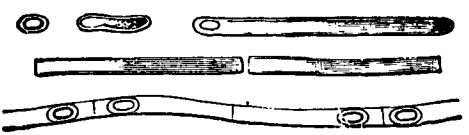

Fig. 6. B. Anthracis.

A list is given of the most common diseases, with the names of the species of organisms which characterise them. Those who desire fuller information will find all they want in Professor Crookshank's *Manual* (Lewis).

Anthrax - - - - - -	*Bacillus anthracis.*
Cholera - - - - - -	*Spirillum choleræ Asiaticæ.*
Croupous pneumonia - -	*Micrococcus pneumoniæ crouposæ.*
Diphtheria - - - - -	*Bacillus diphtheriæ.*
Glanders - - - - - -	*Bacillus mallei.*
Gonorrhœa - - - - -	*Micrococcus gonorrhoeæ.*
Influenza - - - - -	*Bacillus of influenza.*
Leprosy - - - - - -	*Bacillus lepræ.*
Relapsing fever - - -	*Spirillum obermeieri.*
Tetanus (lockjaw) - - -	*Bacillus tetani.*
Tuberculosis - - - -	*Bacillus tuberculosis.*
Typhoid fever - - - -	*Bacillus typhi abdominalis.*

Relation between Pathogenic and Non-Pathogenic Forms.—That there is a relation between disease germs and non-pathogenic bacteria is believed by many, but has not yet been demonstrated. In some cases there is a striking similarity of form, as, e.g., betwen *B. subtilis* and *B. anthracis*. The Darwinian theory would require a common ancestry for the two forms, but the matter still remains in the realms of speculation.

Defences against Bacteria.—The omnipresence of bacteria and their rapidity of reproduction, were it not for the defences which nature provides, would render us absolutely helpless against them. One single individual becomes two in an hour, at which rate over sixteen millions are produced in twenty-four hours. In a week the number that might conceivably result from one individual could only be expressed by fifty-one figures. All the seas of the world would be filled up, and soon the atmosphere would be occupied by nothing else. But the body in health is guarded against them. It is only in a disordered body that this defence fails. Then, too, as is now universally known, the white corpuscles, or phagocytes, in the human blood have the power to absorb bacteria. This discovery of Metschnikoff, though received doubtfully at first, seems now to have become fairly well established. The warfare between these guardian cells and our invisible foes is constantly going on, and we ourselves are able, within limits, to decide the issues of the combat, by careful habits and attention to the laws of health.

Inoculation.—Only a word need be said in reference to artificial defences against the invasions of bacteria. For many years vaccination has been practised in this and other countries. The principle of this prophylactic is, however, different from that which lies at the base of inoculation. The latter process consists in introducing into the body a mild form of the virus of the disease against which protection is sought. Pasteur obtained this milder virus by cultivating the organisms of the disease at a high temperature, as in the case of anthrax. Similar attempts have been made in regard to consumption, cholera, etc., in which animals have been utilised as culture media, but it must be confessed that the results so far have been somewhat disappointing. In the case of hydrophobia the method adopted by Pasteur is that of injecting the hydrophobia poison contained in the spinal cord of a rabbit which has died from the disease into the system of the bitten person. The anti-toxine method applied to diphtheria proceeds on a similar principle. The poison is collected from an affected animal and injected into the system of the patient.

There can be little doubt that these methods are scientifically correct, and we may hope that continued experiments will at length lead to the discovery of reliable media of inoculation for many of the virulent diseases which now afflict humanity.

Cultivation of Bacteria.—No one will give attention to bacteria for long without wanting to experiment in the cultivation of these interesting organisms, and it must not be supposed that this is a field absolutely closed against the amateur. Simple cultures of harmless forms can be carried on without any

unusual apparatus, and even pathogenic kinds can in some instances be grown with nothing more than domestic utensils. It would be advisable to experiment at first with yeast, or *B. subtilis*.

The author's first steriliser was nothing more than a cubical biscuit tin covered with thick felt, and a potato-steamer serves admirably for a steam steriliser. Not much ingenuity is required to make a metal incubator having a double wall, and covered all round and at the top with felt, with a hole at the top for the insertion of a cork, through which a long tubular thermometer has to be thrust. These, with a few test tubes, some cotton wool (sterilised), a little

Fig. 7. Steam Steriliser.

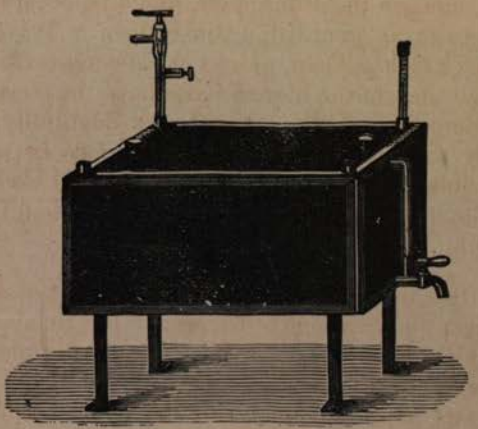

Fig. 8. Incubator.

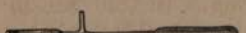

Fig. 9. Page's Gas Regulator.

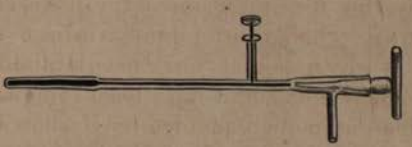

Fig. 10. Reichert's Regulator.

corrosive sublimate and two or three bottles of Pasteur's ingredients for nutritive media will constitute a very fair amateur's outfit, supposing, of course, that he has all he needs for microscopical work. Most people will prefer to purchase their bacteriological apparatus, and a few pounds will be well spent in this way. Messrs. W. & J. George, Ltd. (late F. E. Becker & Co.), publish an illustrated catalogue of such articles, and it is remarkable at what low prices everything that is requisite can now be obtained. A neat steam steriliser, incubator, gas regulator and thermometer registering 200° C., with a few other trifles, may be obtained for a little over three pounds. Everything necessary to amateur work is represented at figs. 7 to 10, and these articles are supplied by Messrs. George at remarkably low prices.

A very interesting experiment is to cultivate a colony of bacteria on potato. Dr. Sims Woodhead gives a lucid description of the method in his volume, to which reference has already been made. He also includes in the Appendix careful instructions as to the preparation of various cultivation media—peptone, agar-agar, serum, etc.—which we strongly recommend to the attention of any who may contemplate taking up this fascinating and useful branch of science. His characterisations of growing bacteria will also be found of the utmost value in the identification of species.

When it is remembered that it is possible by means of not very difficult experiments to detect infectious organisms in the air of our rooms and cellars, in the water we drink and in the food we eat, and that it is a comparatively easy task for the amateur bacteriologist to discover the initial stages of disease by an examination of the blood and the sputum, no further inducement need be held out before the intelligent devotee of the microscope to lead him to give some attention to the subject of this paper.

FOCUSSING MECHANISM FOR PHOTO-MICROGRAPHY.

By Albert Norman,
L.R.C.P., L.R.C.S., L.M. Edin.

IT occurred to me that a method of connecting the fine adjustment of the microscope with the focussing rod in photo-micrography might be useful to some of your readers.

A good deal has been written about the difficulty of getting a slow and even motion to the fine adjustment when focussing at the back of the photo-micrographic camera, and out of reach of the fine adjustment head. The following contrivance has been used for some time by the writer, and with such comfort and success that he prefers it to any other.

It consists of three parts :—

1. The shaft, about 2½ ins. long, carrying at one end a toothed wheel 1¼ in. in diameter, and at the other end a pulley ¾ in. in diameter.
2. A half-inch cog-wheel attached to the focussing rod.
3. The band, connecting the fine adjustment with the pulley.

The shaft with the toothed wheel runs on bearings attached to a framework of wood, which, again, is fixed to the turntable of the apparatus, so that the pulley-wheel is exactly opposite the groove in the fine adjustment head. The cog-wheel on the focussing rod is put into position, so that it works easily in the

toothed wheel, and it is then fixed to the rod by a screw. The band connecting the fine adjustment and the pulley may be made of silk or cord, bees-waxed to prevent slipping. The tension is obtained by means of a fine, but comparatively strong steel spring, to which the ends of the band are attached.

For low or medium power work it does not matter where the spring lies, but for delicate work at 1000 diameters the best position for it seems to be around the fine adjustment head, the groove of which is slightly roughened. Here it grips well, and a sharp focus, once obtained, never alters during exposure, except from causes unconnected with this mechanism.

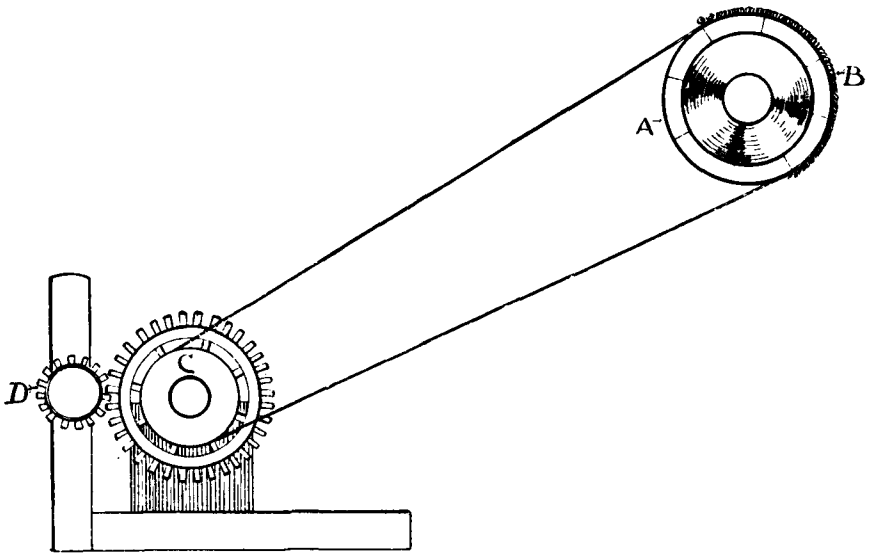

Diagram showing connection between the fine adjustment of microscope and the focussing rod of photo-micrographic apparatus.

A Fine adjustment of microscope.
B Tension spring attached to cord.
C Pulley wheel.
D Cog-wheel on focussing rod.

When visual examination of an object through the microscope is desired, or a fresh field has to be found, the focussing rod is withdrawn half an inch; this disconnects the gearing, releases the rod from its last bearing, and allows the turntable to be swung round. The band connecting the fine adjustment and the pulley is not removed.

The focussing rod works easily on its bearings, and when the best focus is obtained, and the weight of the hand is removed from the rod, the two wheels carrying the band are practically detached from this rod, and, if the tension is uneven, an alteration in the focus will be at once detected and rectified. The writer having with this contrivance photographed successfully most difficult flaggellated organisms, hopes, as the materials necessary are easily obtainable, that the idea may be found of some use to other photo-micrographers.

PHOTO-MICROGRAPHY.

By Procella.

I HAVE practised photo-micrography for the last twenty-five years. I began a considerable time before the introduction of the modern dry plate in 1879-80. Collodion was the sensitive medium then used, and as my business duties only permitted the necessary leisure in the evenings the practice was pursued under considerable difficulty—the chief one being the illuminant.

As my experience may be useful to others I propose to describe very shortly what it has been and in what way I have succeeded in overcoming the difficulties incident to the subject. My apparatus is a very simple one, and has been all constructed with my own hands. The base-board of the apparatus is of yellow pine about 3 feet long, about 8 inches broad and 1½ inches thick. I find yellow pine much more rigid than a harder wood, and it is much lighter. The camera is a quarter plate one, with a bellows having an extension of about two feet. The end of the camera carrying the dark slide is rigidly attached to one end of the board, while the other end of the camera, which is attached to a sliding front, can be moved forward and fixed by a pinching screw at any distance within the limits of the bellows extension. The top of the base-board at each side has narrow strips screwed on within which the front of the camera slides. The camera front has a flange screwed with the same thread as the Dallmeyer half-plate R.R. and carries a tube about 2 inches long which fits it. The microscope is one which I specially made myself for the purpose. It is mounted on two brass trestles which are rigidly screwed to a board which slides within the guides on the top of the base-board. This piece is about a foot long, and it again can be pinched firmly at any position on the base-board. The base-board for this purpose having a groove reaching within 6 inches of each end. Beyond the microscope there is an upright board of thin wood which has an aperture in it of an inch in diameter opposite to the optical axis of the microscope. This aperture is used for adjusting the size of the image wanted, and for focussing by means of a lamp of any kind placed behind it. A small wooden shutter about 3 inches long, whose shape is like that of a vertical section of a sugarloaf rotates at the narrow end upon a screw nail while another screw allows it to fall into position when the lamp is removed. In the centre of the broad end of the shutter a piece of brass tube with an aperture of about $\frac{3}{16}$ths of an inch is screwed, and this tube when the shutter is in position is exactly opposite the optical axis of the microscope. This adjustment is easily made by means of a low power object glass and eye-piece before the shutter is fixed, and when this is done in my case with a fixed microscope, all work is ended. Now, when about to take a photo-micrograph, the microscope and camera are moved along the base-board, with the lamp behind the one-inch aperture, the shutter being swung aside on its nail out of the way, until with the object glass used one is satisfied with the magnification and has obtained a sharp focus. The front of the camera is then pinched firmly down and so is the board on which the microscope is carried. The focus is again examined to see that all is right, a plate is put in the dark slide, this end of the camera covered with a dark cloth, the lamp removed and the small shutter is turned into position, the shutter of the

dark slide is withdrawn, and we are ready for an exposure. I do not turn down the lights in the room. Suppose I am using a Zeiss 35 mm. apochromatic as the objective with a camera extension such as to get 30 inches between the object and the sensitive plate, I push about three-quarters of an inch of magnesium ribbon through the aperture in the small brass tube in the shutter and set fire to the ribbon by means of a match, and this three-fourths of an inch of magnesium ribbon, which will barely take three seconds to burn, will give me a dense negative. I use no condensers with low powers. With this illuminant they are not necessary. The light proceeds from a small point and the rays reaching the object are nearly parallel. Sir Henry Roscoe, in his book on "Spectrum Analysis," states that this light is rich in purple and violet light, the very qualities which affect the sensitive plate most. I have used magnesium now for over ten years, and have constructed more than a dozen apparatus similar to that I have endeavoured to describe for the public laboratories and for private teachers in the city in which I reside. Magnesium ribbon is easily lighted if the end is dipped either in paraffin oil or spirit of wine. To give another illustration of the power of the light. I recently was asked to produce some photo-micrographs of sand, one of these being sand from the desert near Cairo, the other singing sand from one of our western islands. I took two 3×1 slides and spread a very little gum on them, then sprinkled the grains of sand on the gum. I placed the slides on the stage of the microscope with a piece of black paper behind, and using Zeiss 70 mm. apochromatic, I obtained, by means of the gas in the room, as sharp a focus as possible. I then, after the apparatus was in order, placed a board alongside the camera to receive the magnesium oxide as it dropped. I took a short piece of brass tube and pushed about two inches of magnesium ribbon through it, lighted it, and keeping it about a foot from the slide, I burnt about eight or ten inches of the ribbon by pushing the ribbon through the tube as it was consumed. I used no condenser, and in this way I obtained two very fine negatives. Lantern slides have been made from these and they excite the admiration of everyone who sees them on the screen. The light and shade in the prominences and hollows in the sand grains are beautifully rendered. They are at present being reproduced by a photo-mechanical process in the transactions of a geological society. I have taken photo-micrographs of such diatoms as Navicula lyra and N. Splendida by means of Zeiss 4 mm. apochromatic without any condenser by simply burning about six inches of ribbon.

I cannot admire the persistent way in which photo-micrographers will insist upon using oil lamps, even though they are assisted by every possible optical accessory, when they have at their command, if they choose to use it, a light so very effective as magnesium. The rapidity and power of its action, its cleanliness, and the ease with which it can be used is all in its favour. Why waste minutes of valuable time with oil lamps, when a second or two will do the same thing with magnesium? With the above-mentioned 70 mm. objective when I am photographing a transparent object I usually have to place two separate pieces of obscured glass between the light and the object, as otherwise, however small a piece of ribbon I burn, my plate would be overexposed. I do not need to allude to any of the other methods of illumination as I have practised this one

now for so long and find it so well adapted to the end in view by its simplicity and cheapness, that I regard every other, except sunlight, as inferior to it in every way. I invariably use Ilford Ordinary or Empress plates, as from the photo-micrographs I made of the granulation of the silver in these plates which were exhibited at a meeting of the British Astronomical Association two years ago, I found the silver in a finer state of division in them than in those of any of the other makers.

THE ROYAL MICROSCOPICAL SOCIETY.

By a Fellow.

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WERE an accurate record compiled of the various forces which have been at work in the development of microscope stands, objectives, and substage condensers to their present high state of efficiency, we should be astonished at the amount of influence that had been exerted and the important work that had been accomplished by the Royal Microscopical Society. From its inception it has been presided over by the ablest microscopists of the time, the majority of whom have been men of high standing in the scientific world, and specialists in some branch of research to which the microscope has been the handmaid. The president has been aided by secretaries and a council composed of men who frequently were no less distinguished than himself, who ever placed their best services freely at the disposal of the society.

The first president (1840-1) was Professor Owen, afterwards Sir Richard Owen, K.C.B., D.C.L., M.D., LL.D., F.R.S., etc., whose scientific achievements are known throughout the world. At the first annual meeting on the 15th

February, 1841, the society consisted* of 177 members, of whom no less than twenty-two were Fellows of the Royal Society, and included such well-known names as Thos. Bell (professor of zoology at King's College), Birkett (of Guy's), George Busk, F.R.S. (president 1848-9), Sir James Clarke, John Edward Gray (keeper of the zoological department of the British Museum), John Lindley, Ph.D., F.R.S. (president 1842-3), John Kippist (the librarian of the Linnæan Society), the Marquis of Northampton (then president of the Royal Society), Sir John Tomes, Erasmus Wilson, and Joseph Jackson Lister, F.R.S., who has been described as "the pillar and source of all the microscopy of his age." In passing, it may be noted that it was on January 29th, 1840, that the society adopted standard sizes for the glass slips for objects, 3×1 in. and $3 \times 1\frac{1}{2}$ in., which sizes are universally employed to-day. As the list of subsequent presidents is read over, one cannot but be struck by the fact that they were all eminently practical men; some of their names are so familiar to us on account of their work that it seems impossible to dissociate them from present-day microscopy, such, for instance, as George Jackson, M.R.C.S. (1852-3), who gave us the well-known Jackson form of microscope; Dr. William B. Carpenter, C.B., F.R.S. (1854-5), whose book, recently edited and revised by Dr. Dallinger, is the standard work on matters microscopical (it was during Dr. Carpenter's presidency that the standard screw for objectives was fixed and introduced); John Thomas Quekett, F.R.S. (1860) and others. Professor Huxley was a member of the council in 1857, and contributed his first paper to the Society's proceedings during the presidency of Dr. Arthur Farre, F.R.S. (1850-1).

"The society was established for the promotion of microscopical and "biological science, by the communication, discussion and publication of observa- "tions and discoveries relating to (1) improvements in the construction and mode "of application of the microscope, or (2) biological or other subjects of micro- "scopical research."

How perfectly the society has adhered to the lines laid down, can be seen on reference to its Journal, which holds a high position amongst the leading scientific publications. In it are to be found original papers, written by Fellows, which have contributed materially to the advancement of knowledge in matters microscopical. It has also for many years been the centre of communication of information regarding new discoveries and processes in biology, subjects which have often been closely linked with the material well-being of the world at large.

The society has always been especially strong in the mechanical and optical sections of the microscope. Details peculiar to English microscope stands, which must eventually be more fully recognised by Continental manufacturers—such, for instance, as the tripod form of foot, the centring substage and fine adjustment for same, the rackwork draw-tube, the improvement of the fine adjustment and numerous other details which make for perfection—have been nurtured into prominence and acceptance by the society. In the optical section every fresh effort has been encouraged; the substage condenser has been evolved from a makeshift to a system which is as carefully made and needs as skilful employment as the objective, while the introduction of wonderful excellence in objectives of

* "The History of the Royal Microscopical Society," by A. D. Michael, F.L.S., etc. (Journal of the Society, 1895, Part I.)

moderate cost has been fostered and practically compelled by the constant criticisms and encouragement of the Fellows. As a result we have lenses at our disposal only slightly inferior to the apochromats, which have enabled many men to do original and reliable work without being handicapped by the enormous expenditure that was necessary for lenses a few years ago.

To maintain the best traditions of a society which has done such yeoman service in the past is a great responsibility, and calls for constant activity on the part of its council and members. The list of names of the officers which heads this brief notice will afford a guarantee of the maintenance of its vitality and eminence, but this depends in no less degree on the individual Fellows than on the president and council. Communications of investigations undertaken, new theories, and progress that has been made in any branch of microscopical work, always receive a courteous hearing from the society, and frequently valuable assistance is afforded by hints from the ripe experiences of the Fellows. The Journal*, which is issued bi-monthly to the members, contains, in addition to the transactions, a summary of current researches in zoology, botany and microscopy throughout the world, and is an invaluable record for workers. The extensive library and instruments are always at the disposal of members, and the rooms at 20, Hanover Square, are open daily.

Representing, as it does, microscopy in its scientific aspect only, the membership is necessarily limited, and the very high standing of the society has rather tended to discourage workers from applying for admission to its ranks, but all really interested microscopists are entitled to claim its advantages by becoming Fellows. The "toy" microscopist, who uses—or rather misuses—his instrument for curiosity and amusement, is not eligible, but any person who may be desirous of gaining a better understanding of the theory and methods of employment of the most fascinating instrument ever devised, or wishes to be *au fait* in current scientific microscopy, will have no difficulty in finding a Fellow who will nominate him. The secretaries of the society are always glad to render assistance to such persons. The society should have on its roll every earnest worker, and it is the duty of such to afford his best support to the society, not alone for his individual benefit, but for the good of microscopy generally and the vast interests that are interwoven with it.

THE QUEKETT MICROSCOPICAL CLUB.

By G. C. Karop.

HAVING been requested to furnish a short account of the origin and progress of the Q.M.C. for the "Annual of Microscopy," I gladly avail myself of the opportunity, the more so as the sources of information are rather difficult to obtain and the number of those who were associated with its inception and early career is annually growing less.

*Price, 6s. per number to non-members. Each Fellow subscribes £2 2s. annually to the society and receives the Journal as issued. An additional fee of £2 2s. is payable on admission.

The club was founded in 1865. Long before that date, of course, the microscope had been recognised as an indispensable aid to the researches of the naturalist and had also been eagerly taken up by the dilettanti, in this country at least, chiefly on account of the wonders and beauties it was capable of revealing, and partly from the way the instrument lent itself to the invention of subsidiary apparatus, not so much intended for investigation as for the perfect exhibition of prepared objects. The complete microscope of this period with its cabinet of accessories was a wonderful and costly affair. A scientific body, the Microscopical Society of London, already existed, and met the needs of the professional man and the wealthy amateur. But at that time a taste for some kind of scientific recreation was already spreading widely amongst another class, and Natural History Societies were springing up everywhere; an extensive and well-illustrated popular literature came into being, and with the production of a cheaper class of instrument, large numbers of intelligent persons were enabled to purchase and work with the microscope. However excellent in its way the existing society might be, and indeed was, it obviously did not quite correspond with the means or requirements of many, and in May, 1865, the following letter appeared in *Hardwick's Science Gossip*, then edited by M. C. Cooke:—

"PROPOSAL TO LONDON MICROSCOPISTS.—It appears to me that some association amongst the amateur microscopists of London is desirable, which shall afford greater facilities for the communication of ideas and the resolution of difficulties than the present society affords, and which, whilst in no respect hostile to the latter, shall give amateurs the opportunity of assisting each other as members of an amateur society, with less pretentions, holding monthly meetings in some central locality, at an annual charge sufficient to cover the incidental expenses—say five shillings a year—on the plan of the Society of Amateur Botanists. By the publication of this letter, the general feeling of the parties interested will be ascertained, and by this future action determined.—W. GIBSON."

A meeting subsequently took place at No. 5, Hanover Square, W., between Mr. M. C. Cooke, Mr. Bywater and Mr. Ketteringham, and as the result of the discussion of the project it was determined to endeavour to establish a society of amateur microscopists, with the title of "The Quekett Club," and to call a meeting of certain gentlemen known to the conveners as likely to be interested. A meeting was accordingly called for June 14th, at 192, Piccadilly, and was attended by eleven persons. It was considered desirable to found a society of amateur microscopists and a provisional committee of five was appointed to deliberate and report on the best means of carrying out the objects of the meeting. The adjourned meeting was held on July 7th, 1865, at St. Martin's National Schoolrooms, Adelaide Place, Charing Cross, at which about sixty gentlemen were present. At this meeting the title, "The Quekett Microscopical Club," was adopted, the date of meetings and the subscription fixed, and an adjournment made until August 4th, when the election of officers took place.

The first ordinary meeting was held on August 25th, 1865, at 32, Sackville Street, Piccadilly, W., Dr. Edwin Lankester, president, in the chair. The number of members rapidly grew and the meetings were so well attended that the accommodation soon proved far too limited, and after a few months the Club

removed to University College, where by favour of the Council it was permitted to hold its meetings in the spacious Library of that Institution, and continued to do so until the year 1890. At this time the College Librarian represented to his Council that the books in his charge were suffering from the effects of the gas consumed by the various societies using the Library, and although the governing body most courteously placed another room at the club's disposal, it was quite unfitted for the purpose, and a somewhat serious crisis arose. All difficulty, however, was finally overcome, and the club migrated to the new premises of the Royal Medical and Chirurgical Society, at 20, Hanover Square, where it has the use of a fine and well-appointed meeting room with library accommodation, etc. During its life of thirty-two years the club has had eighteen presidents, three treasurers, four secretaries, two librarians and one reporter, Mr. R. T. Lewis having held this office from the very first. Twelve volumes of the Journal have been published up to date, viz., six of the first and six of the second series, and bear witness to the activity of the members in furnishing, and to the editors for arranging, the matter contained in them. Perhaps the most noteworthy contributions have been the considerable additions to the Rotifers of this country, as showing the value of the excursions organised by the club, and also the very valuable series of papers on optical matters contributed at various times by Mr. E. M. Nelson. The cabinet of specimens belonging to the club, amounting in the aggregate to several thousands, has been of inestimable use, to beginners especially, and several revised catalogues have recently been issued, although much remains to be done. The library also contains most of the works required for reference by microscopists, and is yearly expanding—somewhat, indeed, beyond the space available for storage.

Altogether, then, the Quekett Club has more than justified the views of its founders, and taking into consideration the extremely small annual subscription, viz., ten shillings with no entrance fee, it may be said to be one of the most successful and well-managed amateur scientific societies in the kingdom. May it long continue to flourish.

MICROSCOPICAL LITERATURE.

MICROSCOPY has become so wide in its applications and literature on the subject so scattered that it is almost impossible for any worker to keep in touch with the new processes and improvements that are being constantly introduced. It seems possible that a monthly journal that gave a resumé of current events in the microscopical world would be appreciated, and as no publication at a reasonable price is now issued, there would appear to be room for it. It would, however, be necessary that a promise of support not merely by subscription, but by contributions of interest, should be given.

If any readers would be willing to assist in making such a journal a success, the Editor of this Annual would be glad to hear from them and to receive suggestions concerning it.

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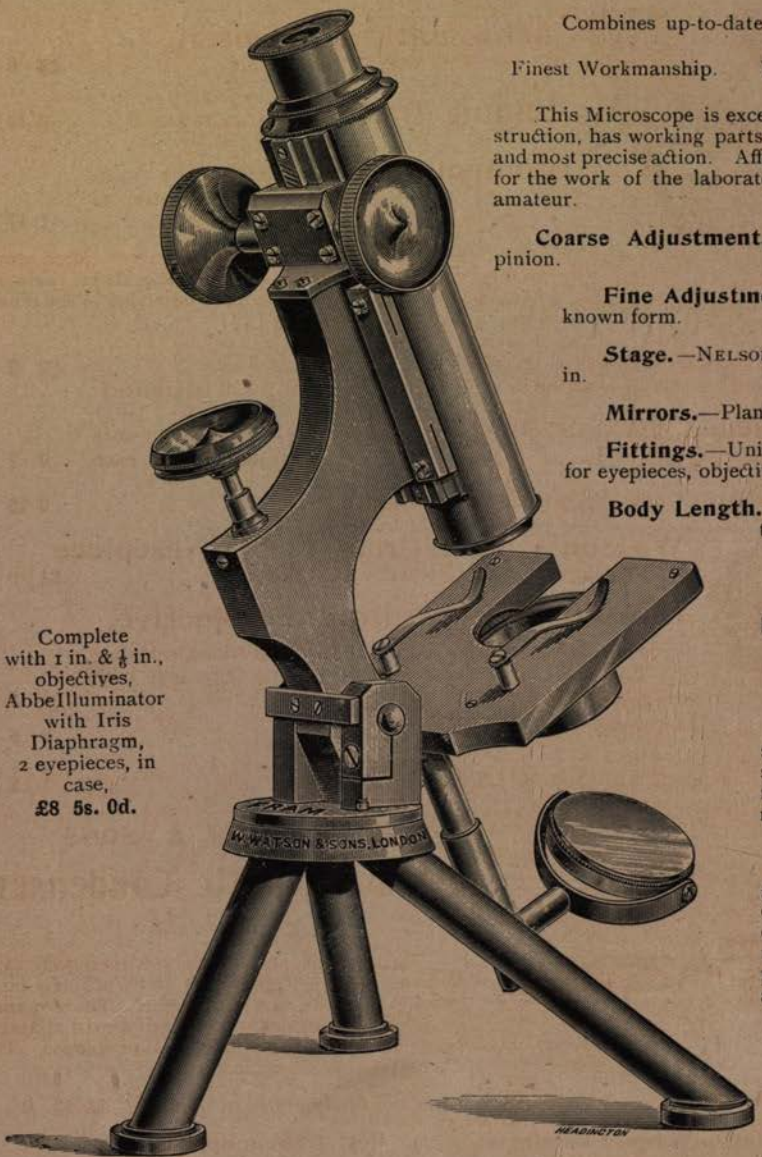

Complete with 1 in. & $\frac{1}{6}$ in., objectives, Abbe Illuminator with Iris Diaphragm, 2 eyepieces, in case,
£8 5s. 0d.

Combines up-to-date Improvements.

Finest Workmanship. Very Moderate Cost.

This Microscope is exceedingly strong in construction, has working parts giving the smoothest and most precise action. Affords every convenience for the work of the laboratory, the student or the amateur.

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Fine Adjustment.—WATSON'S well-known form.

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Mirrors.—Plane and concave.

Fittings.—Universal sizes throughout for eyepieces, objectives, and condensers.

Body Length.—152 m/m, with draw-tube extended 250 m/m.

Height.—11 inches.

Spread of Tripod Foot.—7 inches.

Absolutely rigid in all working positions.

Objectives.—WATSON'S parachromatic series, arranged to be in focus when turned on a nosepiece.

Price, complete with $\frac{1}{6}$ in. and 1 in., or $\frac{2}{3}$ in. or $\frac{1}{2}$ in. parachromatic objectives, arranged to work in the same focal plane; one eyepiece, and mahogany case,

£6 15s. 0d.

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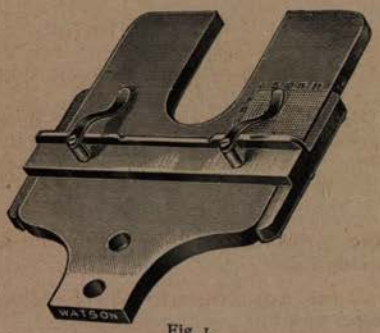

Fig. 1.

Achromatic Condenser, 1·0 N.A., with Iris diaphragm £3 5 0

Sliding Bar to Stage, as shown fig. 1 0 10 6

Compound Substage with rack-work to focus and screws to centre, to replace ordinary under-fitting 1 17 6

In the construction of the "Fram" Microscope, machinery is largely employed, and all the above parts are interchangeable; they can therefore be added to the microscope at any time by the user.

Wright's Finder to Stage as shown in fig. 1 .. .. £0 6 6
(This must be specified at the time of ordering, or the cost will be greater.)

Extra Eyepieces, with initial power engraved upon them, all made to work in same focal plane, nickelled tubes .. .. each 0 7 0

Double Nosepiece, Watson's compact bent form 0 15 0

Fig. 2.

Watson's Dust-Proof Triple Nosepiece (Fig. 2) £1 0 0

1/12 in. Homog: Immn. Objective, Specially suitable for Bacteriological and Biological work, 1·25 N.A.; gives flat field and exquisite definition; with supply of oil 5 0 0

Micrometers, for Eyepiece, 5/0; for Stage.. .. .. 0 5 0

Polariscope, complete with Selenite, 17/6 and 1 5 0

Fig. 3.

W. WATSON & SONS'

Parachromatic Condenser,

1·0 N.A. (Fig. 3.)

This is designed for work with objectives of large aperture. It possesses an exceedingly large *aplanatic aperture*—exceeding 90 N.A. The mounting is a very convenient one, the Iris diaphragm being divided to show the N.A. employed. The diameter of field lens is ⅝ in.

Complete with set of stops .. £3 15 0

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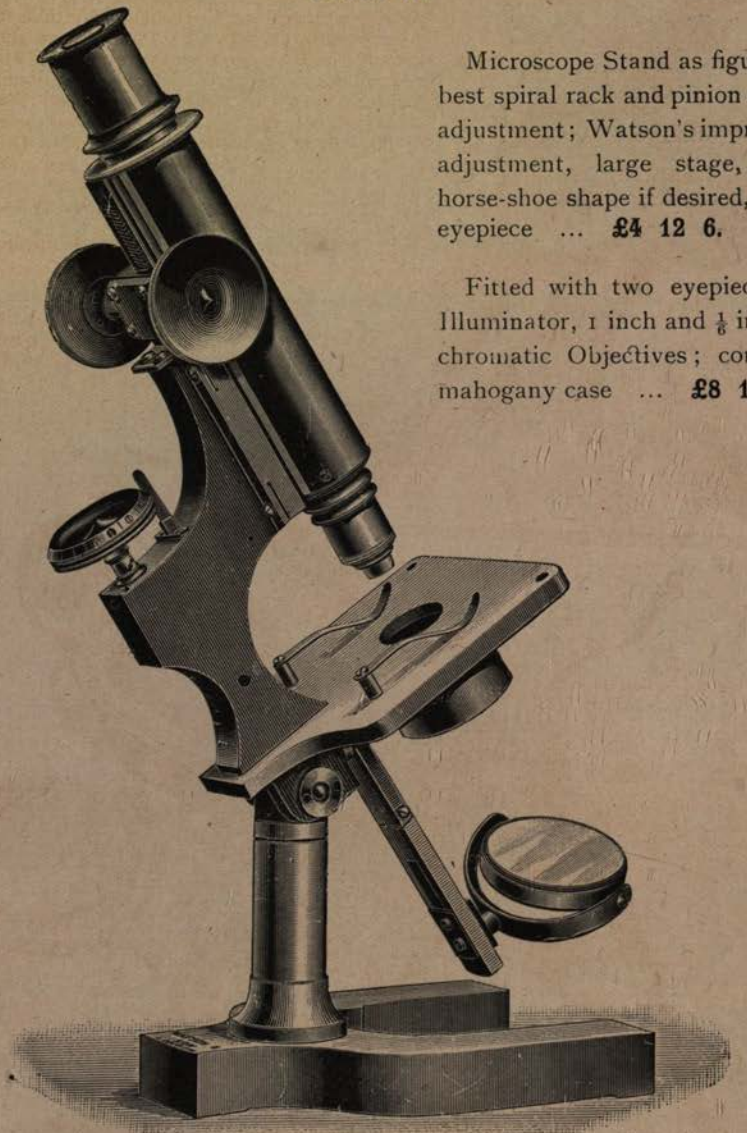
Watson's Edinburgh Student's Microscope

Stand B.



Microscope Stand as figured, with best spiral rack and pinion for coarse adjustment; Watson's improved fine adjustment, large stage, cut out horse-shoe shape if desired, with one eyepiece ... **£4 12 6.**

Fitted with two eyepieces, Abbe Illuminator, 1 inch and $\frac{1}{6}$ inch Para-chromatic Objectives; complete in mahogany case ... **£8 15 0.**

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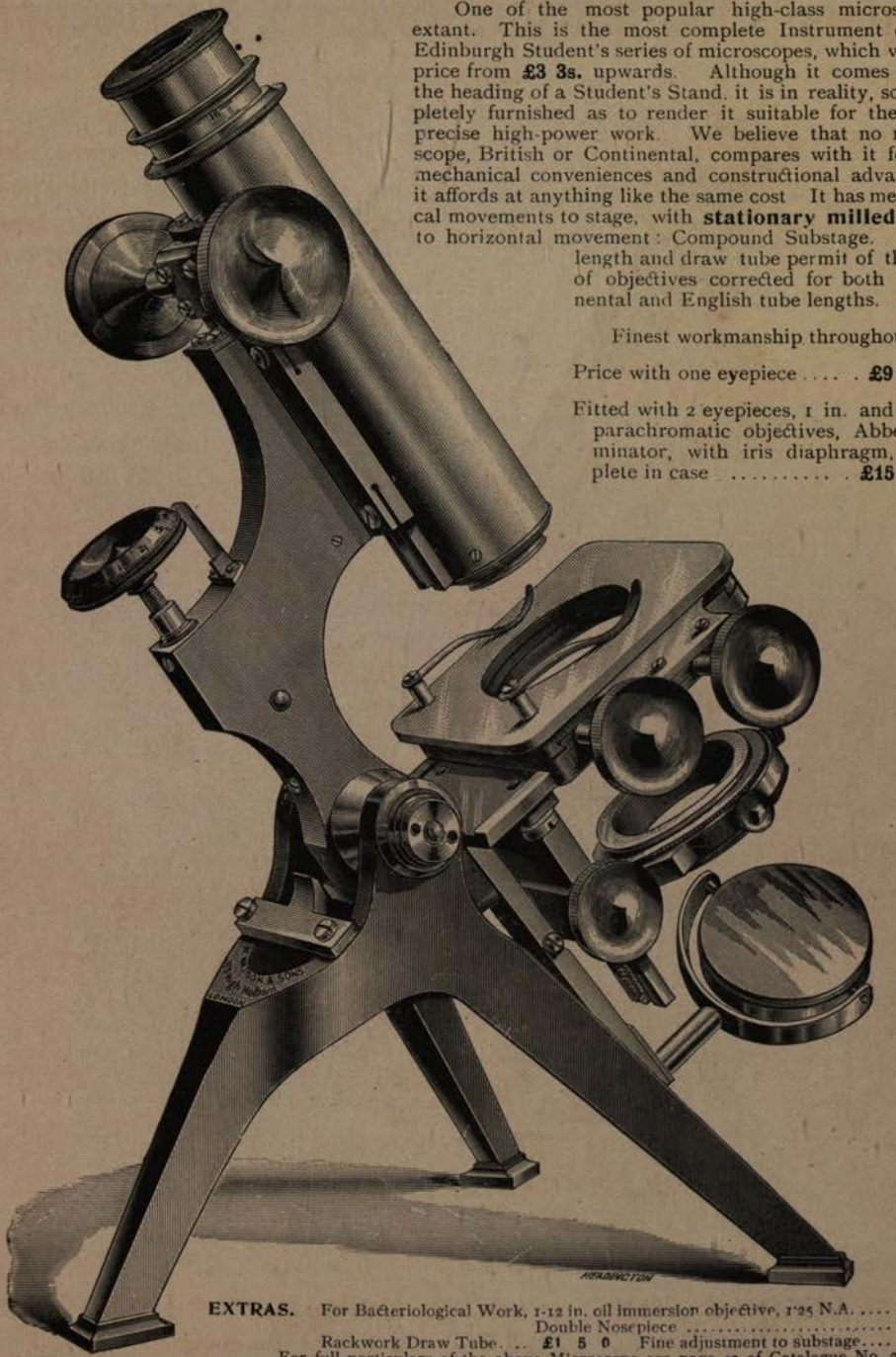
Watson's Edinburgh Student's Microscope Stand "H."



One of the most popular high-class microscopes extant. This is the most complete Instrument of the Edinburgh Student's series of microscopes, which vary in price from **£3 3s.** upwards. Although it comes under the heading of a Student's Stand, it is in reality, so completely furnished as to render it suitable for the most precise high-power work. We believe that no microscope, British or Continental, compares with it for the mechanical conveniences and constructional advantages it affords at anything like the same cost It has mechanical movements to stage, with **stationary milled head** to horizontal movement: Compound Substage. Body length and draw tube permit of the use of objectives corrected for both Continental and English tube lengths.

Finest workmanship throughout.

Price with one eyepiece **£9 10 0**

Fitted with 2 eyepieces, 1 in. and $\frac{1}{6}$ in., parachromatic objectives, Abbe illuminator, with iris diaphragm, complete in case **£15 0 0**

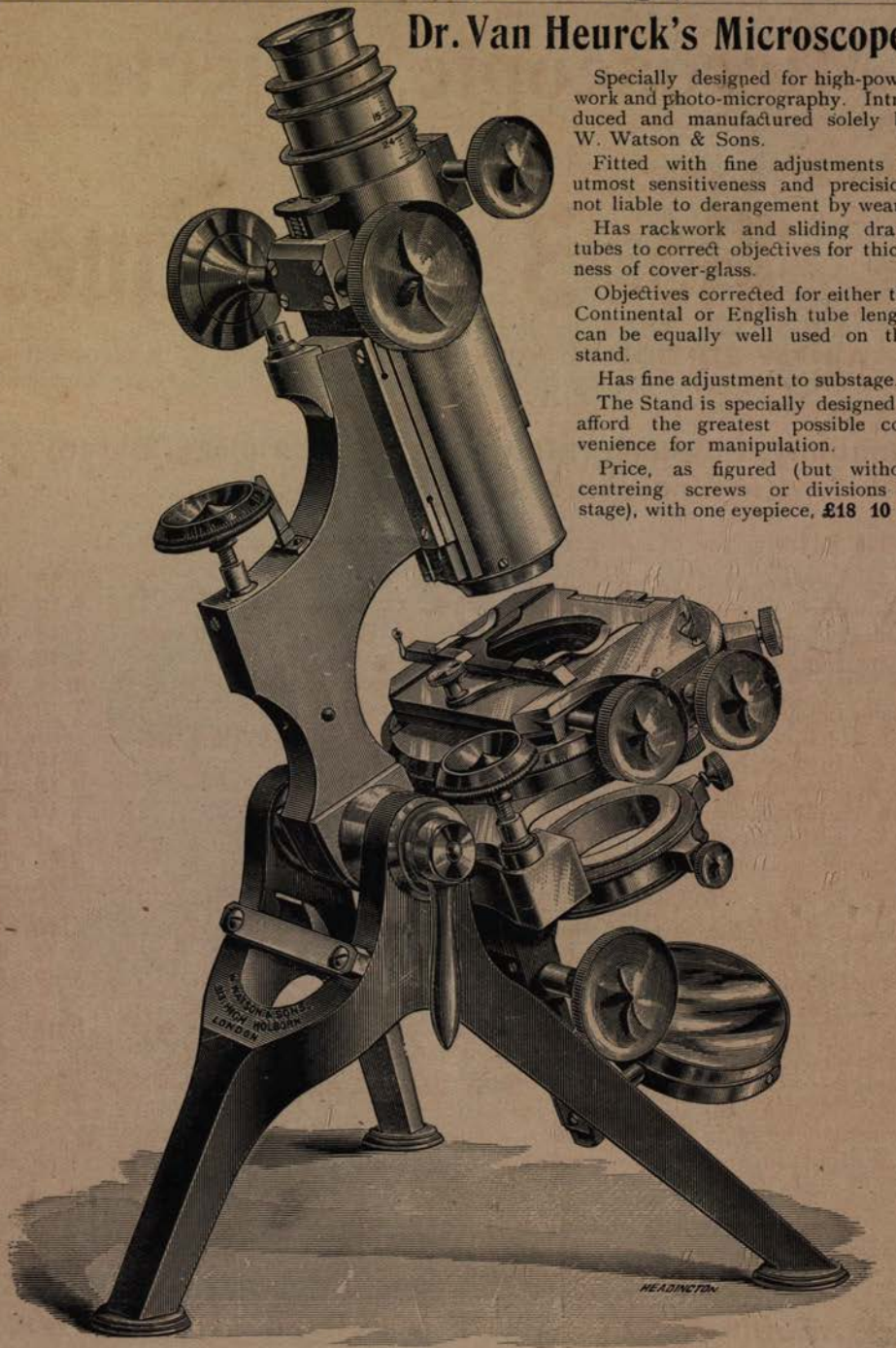
EXTRAS. For Bacteriological Work, 1·12 in. oil immersion objective, 1·25 N.A. **£5 0 0**
Double Nosepiece **0 15 0**
Rackwork Draw Tube. . . **£1 5 0** Fine adjustment to substage. . . . **1 5 0**

For full particulars of the above Microscope see page 42 of Catalogue No. 2.

313, HIGH HOLBORN, LONDON W.C.

W. WATSON & SONS, London, Edinburgh, and MELBOURNE, - - Australia.

Dr. Van Heurck's Microscope.



Specially designed for high-power work and photo-micrography. Introduced and manufactured solely by W. Watson & Sons.

Fitted with fine adjustments of utmost sensitiveness and precision, not liable to derangement by wear.

Has rackwork and sliding draw-tubes to correct objectives for thickness of cover-glass.

Objectives corrected for either the Continental or English tube length can be equally well used on this stand.

Has fine adjustment to substage.

The Stand is specially designed to afford the greatest possible convenience for manipulation.

Price, as figured (but without centreing screws or divisions to stage), with one eyepiece, **£18 10 0.**

For full particulars of this Microscope, see page 8 of Watson's No. 2 Catalogue. Post-free.

W. WATSON & SONS, 313, High Holborn, LONDON, W.C.

W. WATSON & SONS, London, Edinburgh, and MELBOURNE, Australia.

Microscopic Objects.

W. WATSON & SONS'

No. 3 Catalogue.

A NEW EDITION of which is now ready, is a classified list representing a stock of over 40,000 first-class preparations, many of them extremely rare and choice, illustrating every branch of research, including

Anatomy, Physiology, Pathology, Bacteriology, Botany, Entomology, Geology, Diatomaceæ, etc.

The following sets of subjects are fully detailed in the Catalogue **No. 3**:—

Zoology. Set of 12 slides, in case	£0 18 6
Human Eye. Set of 18 slides, illustrating the structure, in case ...	1 12 6
Histology. Set of 24 slides, specially arranged for Student's use, in case	1 15 0
Urinary Deposits. Set of 12 slides, **18/0**, 24 slides, in case	1 16 0
Bone. Set of 8 slides, illustrating growth and structure, in case ...	0 14 0
Pharmacology. Set of 144 slides, in case	7 0 0
Public Health. Set of 36 slides, specially arranged for Student's use, in case	2 10 0
Brewery Fermentations. Set of 12 slides, in case	0 18 0
Paper Manufacture. Set of 24 slides, in case	1 15 0
Test Objects. Set of 12 for various powers, in case	1 1 0
Diatomaceæ. Set of 24 selected specimens, in case	1 15 0

Also Genus Slides, Type Slides, and Test Slides.

Rocks, Typical. Set of 24, in case	1 16 0
Physiography. Set of 12, in case	0 14 6
Opaque Objects. Set of 24 interesting, in case	1 12 6
Insects. Sets of 12 slides, illustrating the anatomy of an insect, several subjects, in case	0 15 0
Polariscope. Set of 24 beautiful polarising subjects, in case	1 7 6
Botanical. Set of 24 Elementary tissues, arranged for Student's use, in case	1 4 0
Botanical. Set of 24 Comparative Anatomy, arranged for Student's use, in case	1 12 6

and many others.

Every slide is guaranteed to be typical of the subject it represents, they are therefore of special advantage for teaching purposes. Catalogue No. 3 containing particulars of above, forwarded post-free on application to—

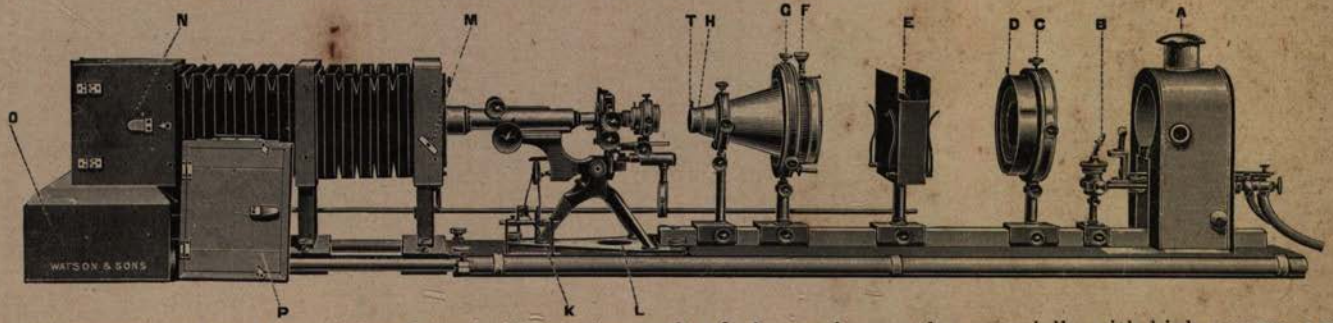
W. WATSON & SONS, 313, High Holborn, LONDON, W.C.

Branches { 16, Forrest Road, EDINBURGH,
78, Swanston Street, MELBOURNE, Australia.

Stringer's Improved Photo-Micrographic Camera and Condensing System.

Designed by Mr E. B. Stringer, B.A., and exhibited before the Royal Microscopical Society, December, 1897.

(See *Royal Microscopical Society's Journal*, April, 1898) Made solely by W. Watson & Sons.



This apparatus has been designed to facilitate the work of photo-micrography, especially with high powers, and to afford an illuminating system more perfectly corrected, more powerful, and more under control than has hitherto been available; and it is unquestionably the most efficient apparatus yet devised. After it has once been set in adjustment any Microscopist can with it produce photographs of the most difficult subjects with unfailing success: it being practically impossible to do otherwise. At first sight it would appear to be complicated in construction, but in actual use it is perfectly simple, and very readily understood. The whole of the optical portion was kindly computed by Mr. E. M. Nelson, it being throughout of Jena glass.

Camera extends to 40 inches: closes to 11 inches. Every part under control. The light is of such brilliance as to reduce the time of exposure to a minimum.

Description.—(*A*) Cowl, covering Zirconium Jet (*B*). (*C*) Centreing Screws for Doublet Parallelising Condenser, 4½ in. diameter. (*D*) Iris Diaphragm. (*E*) Carrier for trough, coloured glasses. (*F*) Condenser, 4¼ in. diameter. (*G*) Centreing Screws for condenser. Cone between *G* and *H* holds water to eliminate heat rays, etc. (*H*) Parallelising lens and (*T*) Iris diaphragm. (*M*) Shutter.

Price of the above Camera to take plates 6½×4¾ in., without microscope, but built to suit any desired size of instrument, complete as shown, **£55 0 0.**

Full particulars of the above are contained on page 103 of Catalogue No. 2. Post-free on application to

W. WATSON & SONS, 313, High Holborn, London, W.C.

Speciality:—PHOTO-MICROGRAPHIC APPARATUS of every description, see No. 2. Catalogue.

Branches: **16, Forrest Road, EDINBURGH;** **78, Swanston Street, MELBOURNE, Australia.**

W. WATSON & SONS, London, Edinburgh, and MELBOURNE, Australia.

W. WATSON & SONS, London, Edinburgh, and MELBOURNE, Australia.

WATSON'S NEW HAND CAMERA

(PATENT),

"THE FRAM,"

(REGISTERED.)

No Guess Work.

Successful Results Ensured.

Takes 24 ¼-plate Films, and gives the whole Picture, without loss of margin, no notching or sheaths being required.

This Camera, briefly described, is of magazine form, the Magazine being an integral part of the Instrument. It works on a simple swing principle, being pivoted at the top side of the Camera.

Method of Changing. When the back is released and the Magazine swung out of the perpendicular, it causes two projecting lips at the front of the Magazine, and on which the Films rest, to disappear, allowing the front Film, which has been exposed, to fall forward into a reservoir beneath together with its backing. This action at the same time throws out two other projecting lips which engage the Film next to the one exposed, and thus prevent it falling into the reservoir. When the Magazine is swung back to the vertical or normal position the second set of projections retire, and the whole of the remaining Films are pressed forward to the front of the Magazine, and there supported again by the projections first mentioned. This constitutes the whole action of changing.

For Simplicity it Cannot be Surpassed. Nor for the same reason can it fail to act.

The whole twenty-four Films having been exposed and projected into the reservoir they may be extracted through the light-tight door in the base of the Camera.

Lens. This is a Rapid Rectilinear of 5-inch focus specially selected for hand-camera work on account of its flat field and depth of focus. It is fitted with iris diaphragm, and can be adjusted to focus objects at varying distances.

Shutter and Finder. The Shutter is one giving time and instantaneous exposures of varying duration, and is fitted with a silvered mirror, by which the picture is reflected on to a Finder measuring 2½ inches by 1⅝ inches, *more than half the actual size of the photograph.* Consequently objects are shown the same size as in the photograph, and can be focussed up to the moment of exposure, thus giving practically the advantages of a Twin Lens Camera in much reduced bulk and at much less cost.

Construction. The Camera is made of seasoned wood, covered in morocco leather, and is of very neat appearance, and best construction throughout.

General Details. Every convenience that many years of experience can suggest AS OF UTILITY has been incorporated, including an automatic recorder, showing the number of exposures made; a Finder for use when the Camera is turned on its side for vertical pictures; a screen to the large focussing Finder, enabling the user to see the picture on the ground glass in the strongest sunlight; and sockets for attaching the Camera to a tripod, either for vertical or horizontal views. Metal parts where possible are in aluminium.

Measurements. The Camera measures 8½ inches by 6¾ inches by 5¼ inches.

Weight. The Camera weighs with twenty-four Films, 3 lbs. 8 oz.

Price, complete with 2 dozen Films, **£8 10s. 0d.**

Extra Cost if Fitted with GOERZ Anastigmat, Series III., **£2 10s. 0d.**

Subject to a Cash Discount of 5 per cent.

• • •

Full particulars of the above together with descriptions of Camera, Lenses, and Accessories of the finest possible quality are contained in Catalogue No. 1, post-free on application to

W. WATSON & SONS, 313, High Holborn, LONDON, W.C.

Branches { 16, Forrest Road, EDINBURGH,
78, Swanston Street, MELBOURNE, Australia.

W. WATSON & SONS, London, Edinburgh, and MELBOURNE, Australia.

SPECTACLES.

Frames made to fit the face. Maximum comfort with elegance Oculists' Prescriptions a speciality.

Full particulars of the above and similar goods, also of Thermometers, Barometers, etc., etc., are contained in Catalogue No. 6. Post-free.

Special illustrated pamphlet on Spectacles, Pince nez and Folders, post-free.

THE "PREMIER" BINOCULAR GLASS.

Finest quality made for race, field or marine purposes. Brilliant definition, long range. Covered crocodile skin, complete in solid leather case **£6 0 0**

Ditto in aluminium . .. **9 10 0**

Smaller size **5 0 0**

Ditto in aluminium **8 0 0**

Every description of Binocular Glass, for field, theatre or marine purposes, also of Telescopes, will be found in Catalogue No. 6. Post-free.

Magic Lanterns

of every description, for the lecturer, demonstrator, and for general scientific and physical experiments.

Lantern Slides.

Mr. Gambier Bolton's studies of animals and many other exclusive and choice subjects are the property of Watson & Sons. Full particulars will be found in Catalogue No. 4.

Animated Photographs.

Watson's Motorgraph. Price, **£12 12s.**

Can be attached to any magic lantern. Films of the latest subjects. Agents for West's beautiful yachting, etc., films. See Catalogue No. 8. Post-free.

Röntgen's "X"-RAY APPARATUS.

Watson's Heavy Discharge Induction Coils, as supplied to the Admiralty and War Department. Everything of the latest and best description for producing effects with Röntgen's "X" rays.

Watson's Army Surgeon's Set, as supplied to Army Surgeons on the Indian Frontier and in Egypt. Completely fitted so as not to be liable to damage in transit, and designed for rough treatment. Photograph and full particulars on application. Prices **£40** to **£50.**

Watson's Hospital Outfit. Consisting of 10 in. Spark Coil with "Vril" Contact Breaker, £33 10s.; 12-Volt Accumulator, £4 19s. 9d.; Rheostat, £1 1s.; 3 Tubes, £5 5s.; Tube Holder, 17s. 6d.; Premier Fluorescent Screen, 12×9½ in., £5 5s.—total, **£50 18s. 3d.**

Iron-bound travelling case for the above, £1 15s. extra.

Watson's Practitioner's Outfit. Consisting of 6 in. Spark Coil, £19 10s.; "Vril" Contact Breaker, 10s. 6d.; 2 Tubes, £3; 8-Volt Accumulator, £2 14s. 6d.; Premier Fluorescent Screen, 10×6 in., £3; Holder for Tube, 17s. 6d.; Rheostat, £1 1s.; Strong Travelling Case, £1 10s.—total, **£32 3s. 6d.**

Full particulars of all the above, and everything connected with "X"-Ray work, are contained in Catalogue No. 7. Forwarded post-free on application.

SURVEYING INSTRUMENTS *are fully described, together with details of* **Mathematical** *and* **Drawing Instruments,** *in Catalogue No. 5. Post-free.*

* * *

W. WATSON & SONS, 313, High Holborn, LONDON, W.C.

(Established 1837)

Branches { **16, Forrest Road, EDINBURGH.**
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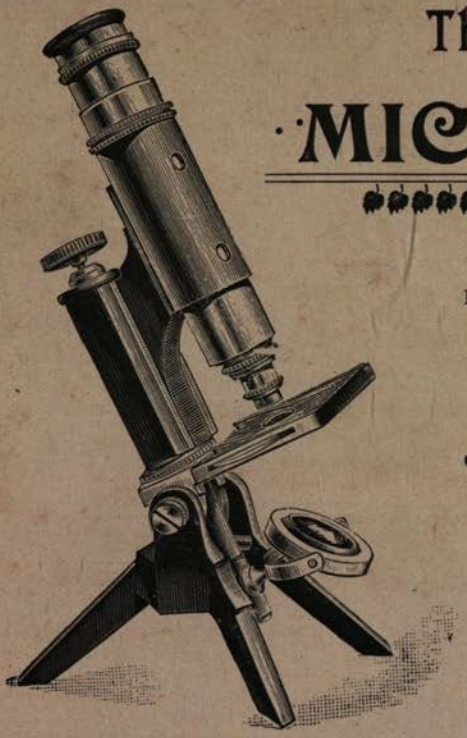

The "WORKER" MICROSCOPE,

With 1 inch and ¼ inch O.Gs.,

In Mahogany Lock Case, complete,

£3 10 0.

James Parkes & Son,

Optical and Mathematical Instrument Works, . .

VESEY STREET, ST. MARY'S,

BIRMINGHAM.

Particulars of other patterns on application.

W. W. Scott,

180, SAUCHIEHALL STREET, **GLASGOW.**

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W. WATSON & SONS'

Microscopes, Objectives, and Accessory Apparatus.

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We make a Speciality of Printing

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for all classes of Printing.

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The Country Press, Bradford;
and
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CARL ZEISS, OPTICAL WORKS, JENA.

London Branch: 29, Margaret Street, Regent Street, W.

Microscopes and Accessories.

Stands VIa, with Abbé Condenser, N.A. 1.0, and attached iris — or with cylinder iris or ordinary cylinder diaphragms.

Photo-Micrographic Apparatus, Etc.

A small, but very portable stand for Laboratory, Naturalists' and Students' use.

New Series of Photographic Objectives for Photo-Micrography and Projection.

SERIES Ia "PLANAR."

Aperture, *f*/4·5.

The first five Objectives of this series are specially corrected for covered objects.

No. 1 equivalent focus 20 m/m, and No. 2 35 m/m, fit the screw-thread of the microscope.

New Combined Horizontal and Vertical Camera for Photo-Micrography.

Can be used with equal facility for either position.

Full descriptive pamphlet free.

The following Illustrated Catalogues sent free on application, specifying which required: —

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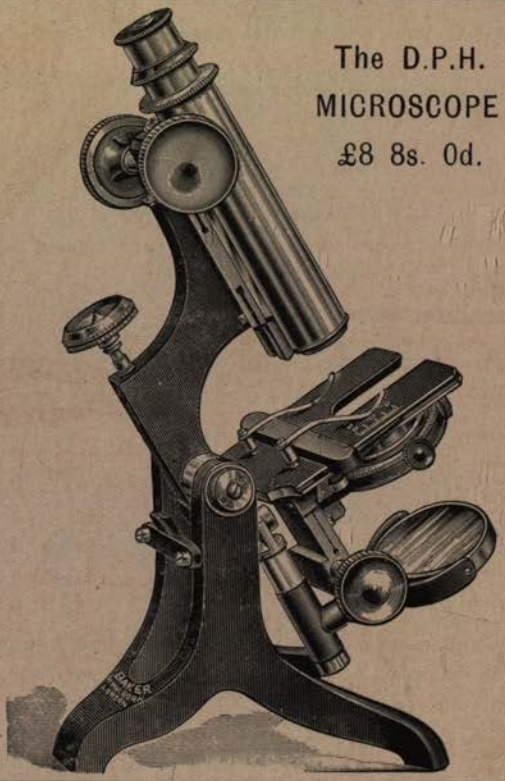
SPECIMENS.

£3 3s. 0d. Educational Sets a speciality.

A list of 5,000 Diatoms on application.



The D.P.H.
MICROSCOPE
£8 8s. 0d.

STAINS.

All the latest stains after Ehrlich, Mayer, etc., from Dr. Grübler's laboratory kept in stock.

NEW MODELS IN MICROSCOPES.

MECHANICAL STAGE—NEW ATTACHABLE PATTERN.

MICROSCOPE CATALOGUE 1898-9. NOW READY. NEW ISSUE.

ALSO CATALOGUES OF SURGICAL AND SURVEYING INSTRUMENTS, FIELD GLASSES, ETC.

WE LEND SPECIMENS.

ROSS' NEW

Anglo-Continental Microscope Stand.

This instrument has been specially designed to meet the modern requirements for the various scientific purposes to which the Microscope is applied, particular attention having been given to eliminate the weaknesses and defects existent in Stands of English and foreign manufacture, while retaining the practical improvements of both constructions.

Absolute steadiness is secured by making the foot of a circular form, segments being cut away from the under side, leaving a triple support. The short pillars which sustain the upper parts are situated towards the margin of the ring, so that the whole weight is thrown centrally upon the foot when the instrument is in an upright position. When inclined from the trunnion-axis at the top of the pillars the latter may be turned upon the firm and reliable rotary fitting upon which they stand, causing the inclined limb to assume a reversed position over the circular base, so that the centre of gravity is again brought directly over the foot, even when the body is turned into the horizontal position for purposes of Micro-photography.

	DESCRIPTION.	Monocular, including one Eyepiece. £ s d.	Binocular, including a pair of Eye-pieces. £ s d.
No. 1.	Microscope Stand, with circular or folding tripod foot ..	25 0 0	30 0 0
No. 2.	Dittto, ditto	21 0 0	25 0 0
No. 3.	With circular foot	17 0 0	21 0 0
	With folding tripod	17 0 0	—

Stands Nos. 2 and 3 are similar in construction to No. 1, differing only in size and in the exceptions mentioned above. They are recommended when portability is desired, and all apparatus used with the largest size may be applied to these.

For full particulars, see complete Catalogue.

ROSS, LTD., Opticians,

111, New Bond Street, LONDON. W. and 31, Cockspur Street, Charing Cross, S.W.

ESTABLISHED 1830. *MANUFACTORY—CLAPHAM COMMON.*

ROSS'

New 'Industrial' Microscope

Stand with fine Adjustment and Double Nosepiece.

FOR

Farmers, Horticulturists, and Elementary Examinations

OF ALL KINDS.

The great utility of Microscopical research to purposes of advanced Agriculture being now so fully recognised, and a less costly instrument than those usually supplied for more complex investigations needed, a Stand with the requisite accessories has been specially designed for the use of farmers, and in those industries that deal with produce and raw materials

A Microscope free from any unnecessary complication, while combining efficiency with stability, is not only desirable, but it is practically the only instrument that will satisfy this want.

Ross' "Eclipse" Student's Microscope (which has become so extremely popular), uniting in itself these requirements and possessing a large size stage and general facilities for easy manipulation, would with suitable modifications be eminently efficient. This form of construction has therefore been adhered to in the new model, and the usual arrangements maintained with the exception of the fine adjustment, which on account of the class of objects to be observed is unnecessary.

This simplification allows of a really good and effective instrument being produced at a most reasonable price.

Should the refinement of a slow motion be considered essential in individual circumstances, it can be provided or added at any time at a small extra charge.

The instrument is provided with a glass dish to contain liquids or manifold objects, which may be moved on the stage to bring the various particles under observation. A fitting beneath the stage carries a plate with diaphragm apertures to modify the light, and, as Seeds, Fibres and other opaque objects form a large proportion of those to be examined, this substage plate has a space between the perforations, which, when brought into position, provides a dark ground by preventing the passage of light from underneath. The fitting is removable to allow of the substitution of an iris diaphragm if required.

For the better lighting of non-transparent objects a condensing lens may be advantageously used and is easily adjusted in one of the openings that receive the fittings of the spring clips on the stage.

Price of Microscope Stands.

With inclining limb, the choice of 1½ in., 1 in., or ½ in. objective, eyepiece, mirror, rack adjustment, substage plate, and glass dish	£3 3 0
Additional objectives as named above	0 12 6
Fine adjustment	1 1 0
Iris diaphragm fitting stage	0 10 6
Condensing Lens ditto	0 5 6
Double Nosepiece	0 15 0
White wood case, stained	0 5 6
Mahogany case	0 10 0

The above prices are for net prompt cash.

ROSS' NEW MODEL

Medical School and Educational Microscope.

This new Microscope, which is a modification of the popular Ross' Eclipse Stand, has been designed to provide students at the outset of their work with a thoroughly good instrument at a comparatively small initial outlay, but admitting of subsequent addition of parts without structural alteration, rendering it ultimately capable of doing the most advanced work and making it a complete and thoroughly efficient instrument at a less cost than most students' microscopes, whether English or Continental. Cheap instruments of this description often have to be abandoned after the first year's work, and a further outlay is then incurred for a more expensive microscope. This waste may be avoided if the student is provided in the first instance with this New Stand, which has simply to be modified at small expense to make it into the high-class instrument that has by that time become a necessity. Its construction is substantial and all its different parts are well fitted, and it will be found perfectly steady in all positions, even when used with the highest power objectives.

The stage is sufficiently large to bring into the field of view every portion of a bacteriological cultivating trough, being 2½ in. from centre to pillar.

An entirely new but simple device has been applied to the substage for the manipulation of the Abbé Condenser and Iris diaphragm independently of each other. By this means they are readily removed out of the optic line, thus effecting a great saving of time. This fitting, which is complete in itself, can be added to the stand at any future time if not required in the first instance.

For a small extra charge the foot of the instrument can be made to reverse and lock, so as to bring its longest spread under the body tube when the instrument is to be used in a horizontal position for photography or drawing.

Microscope Complete, as described, comprising—

	£	s.	d.	£	s.	d.
Medical School Stand, with ⅔ and ⅙ Object-glasses, Eyepiece, and Mahogany Case	6	12	0			
New Substage arrangement with double-swing arm and rack and pinion adjustment	1	8	0			
Abbé Condenser	0	15	0			
Angular double Nosepiece	0	15	0			
Iris Diaphragm	0	10	0			
				10	0	0
Microscope in case with apparatus as above and an extra Eyepiece, but without Object-glasses				8	0	0
Microscope in case, with ⅔ and ⅙ Object-glasses and Eyepiece, but without other apparatus				6	12	0
Microscope in case with eyepiece, but without apparatus or object-glasses				4	7	0

Extras.

Reversing Foot	0	10	0
Triple Nosepiece	1	6	0
Eyepieces each	0	5	0
⅛ Object-glass for Biological work	2	10	0
1/12 Object-glass (Oil Immersion) N.A. 1·2	5	0	0

The above Prices are for net prompt Cash.

ROSS' NEW....

Petrological Microscope

"ECLIPSE" STAND.

As supplied to the University of London, Science and Art Department, South Kensington, and other Educational Institutions.

This Microscope is designed to provide a thoroughly reliable instrument for Students in Petrology.

In size and form it is similar to the Ross' Eclipse Stand with the new reversing foot arrangement, also the diagonal rack and spiral pinion.

The stage is circular, revolving, and the periphery divided to 360°.

The Analyser, which can be drawn out when not needed, is fitted into the lower end of the body tube, where also a slot is cut at the angle of 45° for the insertion of quartz wedge, etc.

The Polariser is pivoted to swing immediately out of the field when so required, and it has a circle divided into 8, clicked at 0° and 180° to indicate when the Nicols are crossed.

The Eyepiece is furnished with crossed webs, and readily drops into a slot.

The milled head of the Micrometer Screw is divided to measure $\frac{1}{500}$ of an inch motion of the fine adjustment.

Plane and Concave Mirrors are provided.

PRICE.

	£	s.	d.
With one Eyepiece, 1½ inch and ¼ inch Object Glasses, Double Nose-piece, Polarising and Analysing Prisms and Klein's Quartz Plate, in Mahogany Case	10	10	0
If fitted with internal sliding tube for carrying enlarging lens .. .. extra	0	12	6
Self-centering action to stage .. .. ,,	0	18	0

Additional Apparatus for Petrological "Eclipse" Stand.

	£	s.	d.
Analysing Prism fitting over Eyepiece, with divided circle	1	5	0
Calespar Plate for Stauroscopic examination	0	10	6
Quarter Undulation Plate	0	10	6
Quartz Wedge (Mounted)	1	1	0
Converging Lenses over Polariser for the study of the interference figure	1	1	0
Mounted Lens to enlarge the same	0	10	6
Camera Lucida	0	7	6

Rock Sections.

THE "KENSINGTON" SET OF IGNEOUS ROCKS.

	£	s.	d.
The Set complete, in Polished Pine Box, with 6 trays, 36 sections in all	2	14	0
The Slides separately, each	0	1	6
Polished Pine Box, to hold 3 dozen Slides	0	2	6
,, ,, ,, 6 ,, ,, ...	0	3	6

Superior Slides of all the important Types of Rock can be had at the rate of **1/6** each.

The Above Prices are all for net prompt Cash.

ROSS'

Bacteriological Microscope.

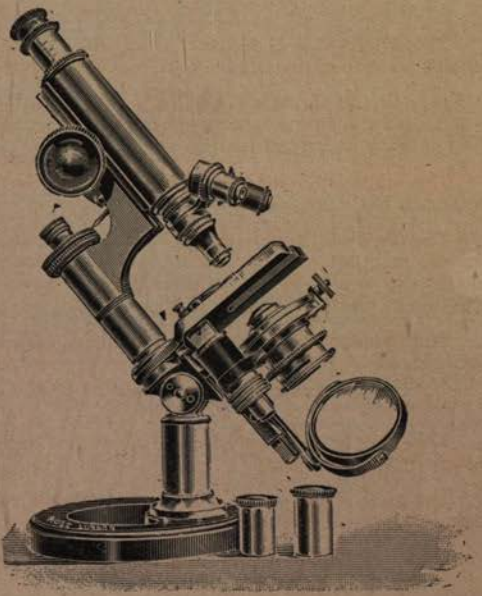
This Microscope has been specially designed for those taking up the study of Bacteriology. The instrument is one of the steadiest ever constructed for this purpose, and the inclination to tilt, so prevalent in most stands, is obviated by the method of mounting upon a circular foot (as illustrated), or on tripod or pillar form if desired.

The stage is firmly fixed between two main parts, and its aperture is of the horseshoe form, which affords convenient space for the finger to lift the slide to readily bring the oil in contact when an immersion lens is used. This stage is provided with clip springs, or a sliding dovetail slip with rectangular divisions if so ordered.

This instrument is fitted with a new centering Substage.

It has large mirrors, plane and concave, with a fitting so arranged that any degree of obliquity can be obtained. It is planned to secure the adjustment of the light in the smoothest and readiest way possible.

Nosepieces (double or triple) may be adjusted so that the objectives focus in the same plane, thus saving a considerable amount of time refocussing each lens.



Price.

	£	s.	d.
Packed in mahogany case, with one Eyepiece	13	10	0
Sliding Object Carrier, with rectangular divisions, extra	0	15	0
Mechanical Stage	3	10	0
Abbé Condenser, with Iris and Central Stops, N.A. 1·40	2	12	0
,, ,, ,, ,, N.A. 1·20	2	7	0
½ in. Oil-Immersion Objective 1·25	7	10	0
1/12 in. ,, ,, 1·2	5	0	0
⅛ in. ,, ,, 1·2	7	0	0

The above Prices are for net prompt Cash.

Mounted Objects for the Microscope.

ROSS, LTD., have a very large and varied selection of mounted objects, consisting of Animal, Vegetable and Mineral Substances, Objects for the Polariscope, for the Binocular Microscope, for the Oxy-Hydrogen Lantern Microscope, etc., etc.

Residents at a distance can have a large assortment of objects sent for selection on giving a reference or sending remittance and defraying carriage both ways, and any damage during transit. The slides not chosen to be returned within one week from the date of their leaving the establishment.

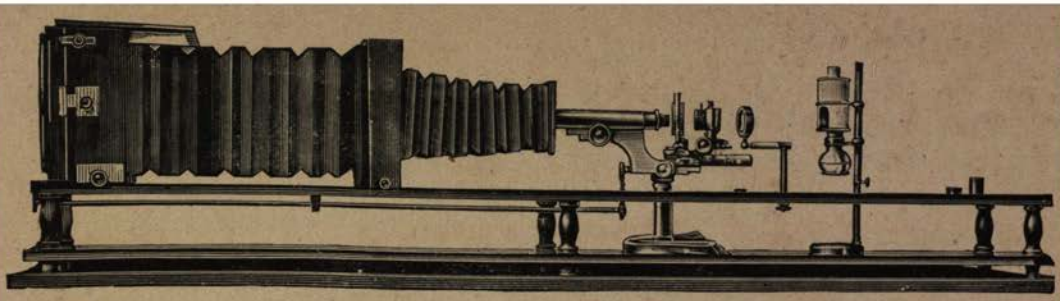


Photo-Micrographic Cameras.

Size of Camera.	Length of Baseboard.	Extension of Bellows, including cone.	Price, exclusive of any necessary adapting.
4¼ × 3¼	48 inches.	18 inches.	£11 0 0
6½ × 4¼	60 ,,	30 ,,	13 0 0
8½ × 6½	70 ,,	36 ,,	15 0 0
10 × 8	80 ,,	44 ,,	18 0 0
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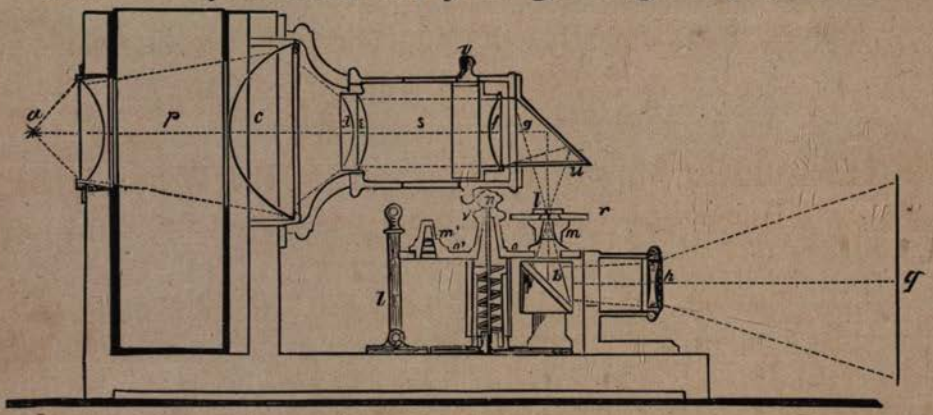

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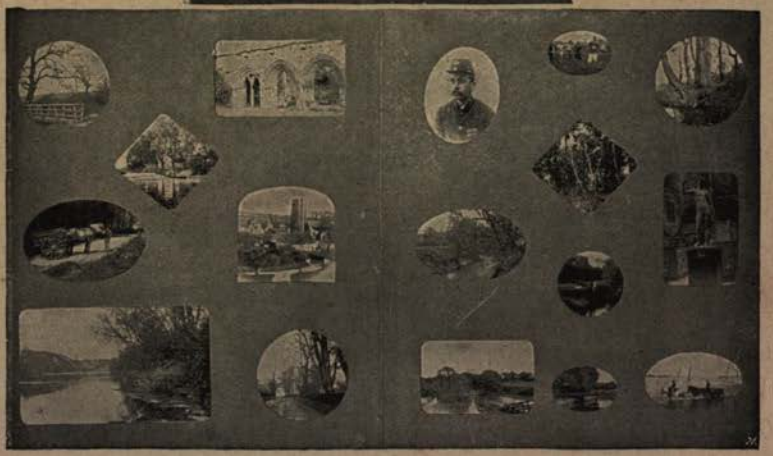

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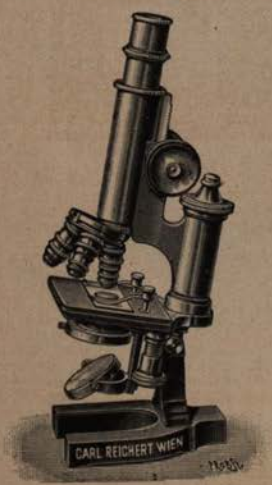

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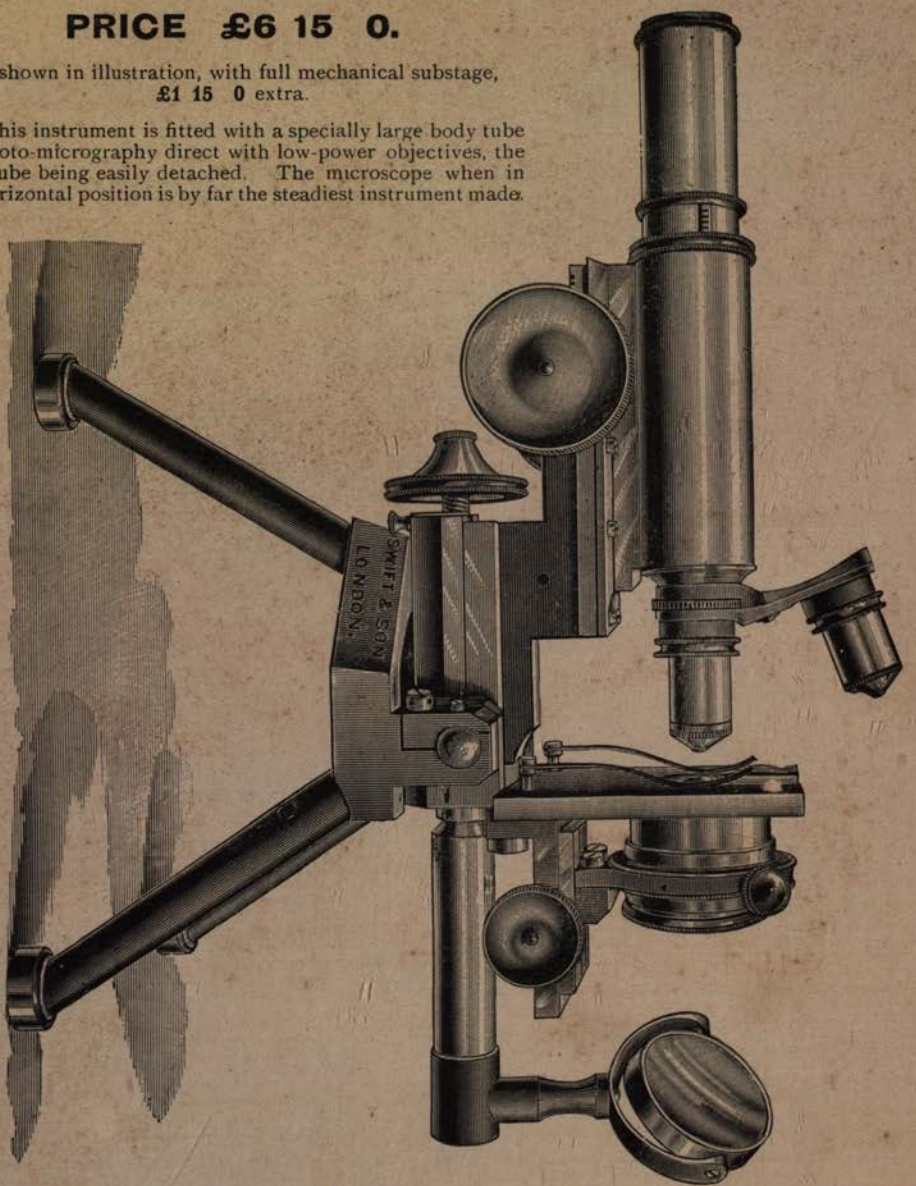

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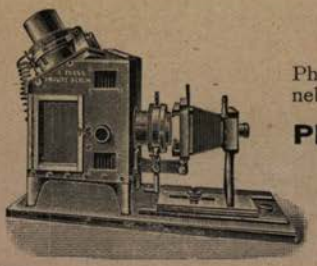

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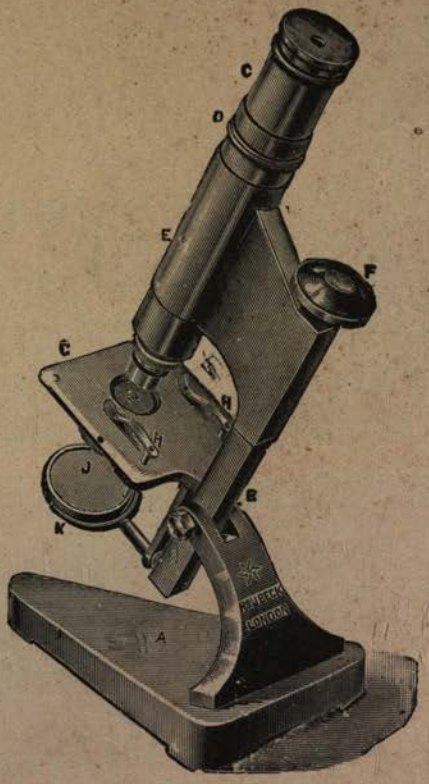

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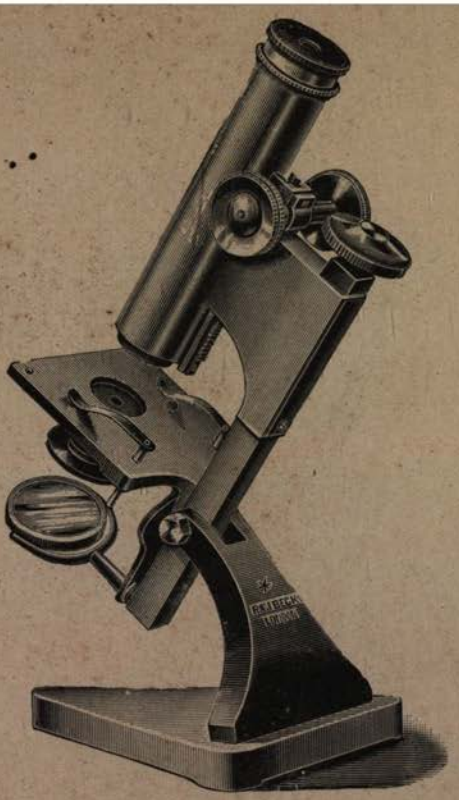

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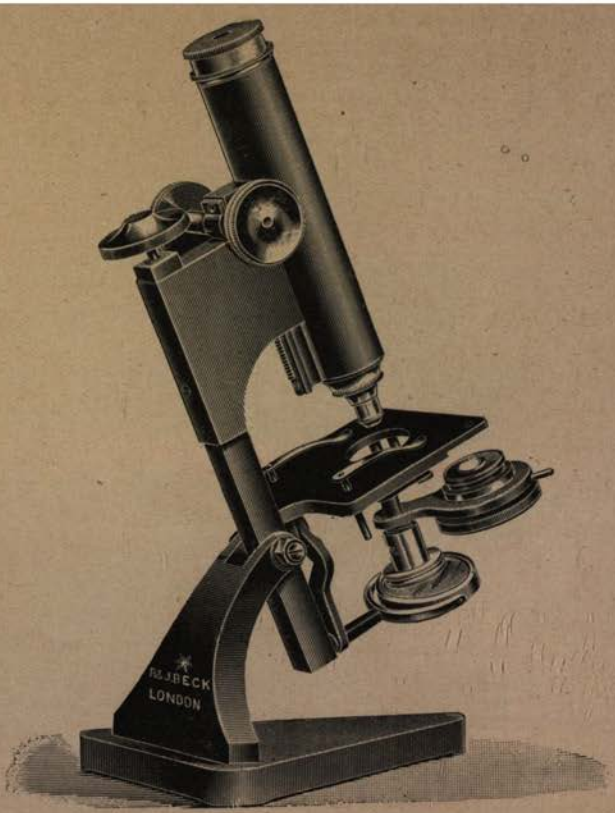

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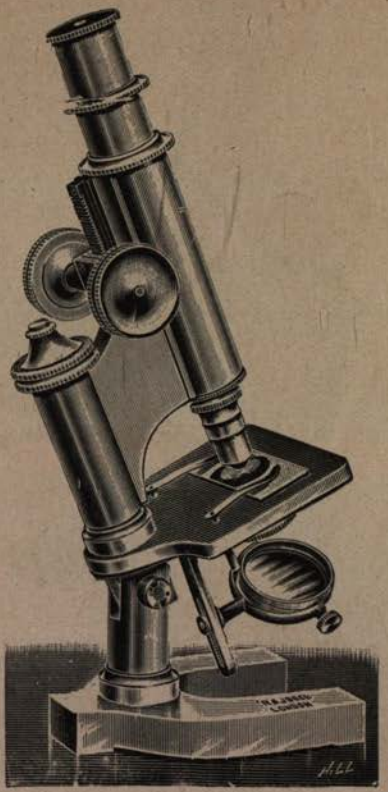

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	,, 803. ⅓ inch (6 mm.) do. 1 1 0	
	Magnifying Power from 38·5 to 270.	6 16 0
25H	**STAND IN CASE** £4 13 0	
	No. 364. 2 Eyepieces, Nos. I. and II. 0 10 0	
	,, 802. ⅔ inch (14 mm.) Object Glass 1 12 0	
	,, 804. ⅙ inch (4 mm.) do. 1 10 0	
	Magnifying Power from 54 to 400	7 5 0
25N	**STAND AS ABOVE** £4 13 0	
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	,, 802. ⅔ inch (14 mm.) Object Glass 0 12 0	
	,, 804. ⅙ inch (4 mm.) do. 1 10 0	
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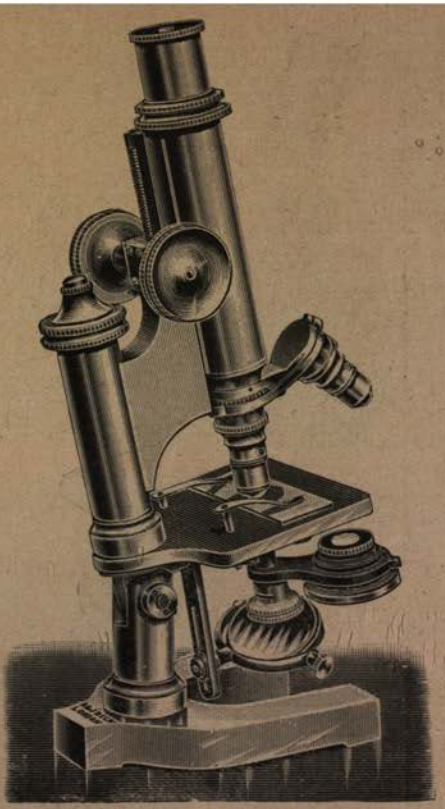

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29K	**STAND IN CASE**	£5 8 0			
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	,, 912. Abbé Condenser with Iris Diaphragm	0 15 0			
	,, 802. ⅜ inch (14 mm.) Object Glass	0 12 0			
	,, 804. ⅛ inch (4 mm.) do.	1 10 0			
	Magnifying Power from 54 to 400.		8	15	0
29L	**STAND IN CASE**	£5 8 0			
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0			
	,, 912. Abbé Condenser with Iris Diaphragm	0 15 0			
	,, 801. 1 inch (22 mm.) Object Glass	0 12 0			
	,, 803. ¼ inch (6 mm.) do.	1 1 0			
	,, 810. 1-12 inch (2 mm.) Oil Immersion do.	4 0 0			
	Magnifying Power from 38·5 to 880.		12	6	0
29N	**STAND AS ABOVE**	£5 8 0			
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0			
	,, 802. ⅜ inch (14 mm.) Object Glass	0 12 0			
	,, 804. ⅛ inch (4 mm.) do.	1 10 0			
	,, 810. 1-12 inch (2 mm.) Oil Immersion do.	4 0 0			
	,, 912. Abbé Condenser	0 15 0			
	,, 192.* Triple Nosepieces..	1 4 0			
	Magnifying Power from 54 to 880.		13	19	0

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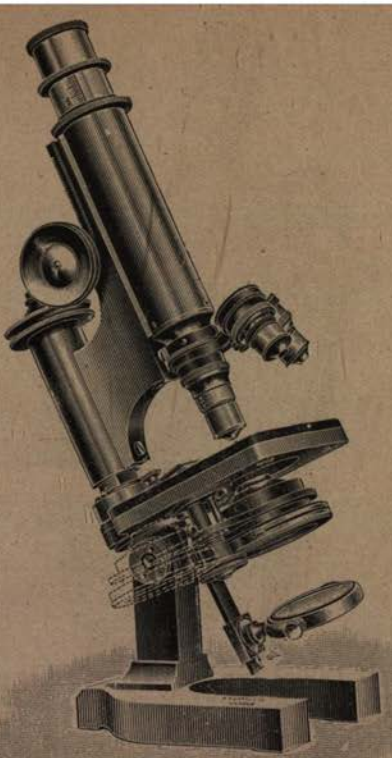
BECK'S MICROSCOPES



No. 53.—THE "CONTINENTAL MODEL" MICROSCOPE.

This Instrument is one of our latest productions for Bacteriological work, and is provided with a Spiral Rack and Pinion Coarse Adjustment, and our latest form of Fine Adjustment operated by the large Micrometer Screw Milled Head. The Nickel-Plated Draw Tube is engraved in the mm. Scale, and indicates how much Mechanical Tube Length is in use. The Large Square Stage has a Vulcanite surface. The Spiral Screw Focussing and Swinging Substage carries our largest-sized Abbé Condenser, and the Instrument is provided with an adjustable Double Mirror on a Swinging Arm, and the whole packs into a polished mahogany case, with lock and key and handle.

No.		£	s.	d.
53	**STAND ONLY**, no Object Glasses, no Eyepieces, no Condenser, in Mahogany Case ..	**6**	**5**	**0**
53K	**STAND AS ABOVE** £6 5 0			
	No. 264. 2 Eyepieces, Nos. I. and II. 0 10 0			
	,, 802. ⅔ inch (14 mm.) Object Glass 0 12 0			
	,, 804. ⅙ inch (4 mm) do. 1 10 0			
	,, 911. Abbé Condenser, 1·0 N.A., with Iris Diaphragm 1 15 0			
	Magnifying Power from 54 to 400. ————	**10**	**12**	**0**
53M	**STAND AS ABOVE** £6 5 0			
	No. 364. 2 Eyepieces, Nos. I. and II. 0 10 0			
	,, 801. 1 inch (22 mm.) Object Glass 0 12 0			
	,, 803. ¼ inch (6 mm.) do. 1 1 0			
	,, 810. 1·12 inch (2 mm.) Oil Immersion do. 4 0 0			
	,, 911. Abbé Condenser, with Iris Diaphragm 1 15 0			
	,, 392.* Double Nosepiece 0 12 6			
	Magnifying Power from 38·5 to 880. ————	**14**	**15**	**6**
53N	**STAND AS ABOVE** £6 5 0			
	No. 364. 2 Eyepieces, Nos. I. and II. 0 10 0			
	,, 802. ⅔ inch (14 mm.) Object Glass 0 12 0			
	,, 804. ⅙ inch (4 mm) do. 1 10 0			
	,, 810. 1·12 inch (2 mm.) Oil Immersion do. 4 0 0			
	,, 911. Abbé Condenser 1 15 0			
	,, 192.* Triple Nosepiece 1 4 0			
	Magnifying Power from 54 to 880. ————	**15**	**16**	**0**

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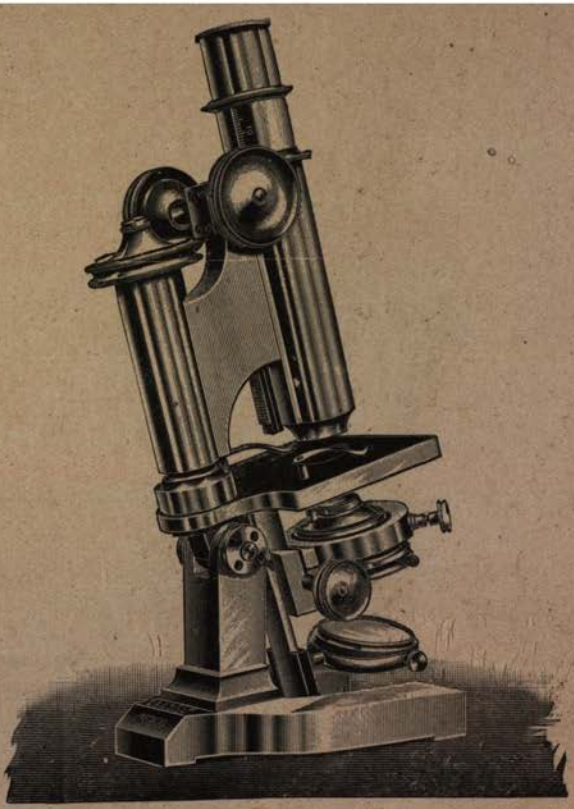
BECK'S MICROSCOPES



No 52.—THE "CONTINENTAL MODEL" MICROSCOPE.

This Instrument is provided with a Spiral Rack and Pinion Coarse Adjustment, and has our latest form of Fine Adjustment operated by large Micrometer Screw Milled Head. The Nickel-Plated Graduated Draw Tube is engraved in the mm. scale, and indicates the amount of Mechanical Tube Length in use. The Large Square Stage has a Vulcanite Surface. The Substage is of the most approved pattern, and will take all large-sized apparatus, it has Rack and Pinion Focussing Arrangements and Screw Centring Adjustments. The Adjustable Double Mirror is fitted to a Swinging Arm, and the whole Instrument packs into a polished mahogany case with lock and key and handle.

No.			£	s.	d.
52	**STAND ONLY,** no Object Glasses, no Eyepieces, no Condenser, in Mahogany Case ..		**7**	**0**	**0**
52K	**STAND AS ABOVE**	£7 0 0			
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0			
	,, 802. ⅔ inch (14 mm.) Object Glass	0 12 0			
	,, 804. ¼ inch (4 mm.) do	1 10 0			
	,, 911. Abbé Condenser, 1·0 N.A., with Iris Diaphragm.. ..	1 15 0			
	Magnifying Power from 54 to 400.		**11**	**7**	**0**
52M	**STAND AS ABOVE**	£7 0 0			
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0			
	,, 801. 1 inch (22 mm.) Object Glass	0 12 0			
	,, 803. ¼ inch (6 mm.) do	1 1 0			
	,, 810. 1-12 inch (2 mm.) Oil Immersion do...	4 0 0			
	,, 911. Abbé Condenser, with Iris Diaphragm	1 15 0			
	,, 392.* Double Nosepiece	0 12 6			
	Magnifying Power from 38·5 to 880.		**15**	**10**	**6**
52N	**STAND AS ABOVE**	£7 0 0			
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0			
	,, 802. ⅔ inch (14 mm.) Object Glass	0 12 0			
	,, 804. ¼ inch (4 mm.) do.	1 10 0			
	,, 810. 1-12 in. (2 mm.) Oil Immersion do.	4 0 0			
	,, 192.* Triple Nosepiece..	1 4 0			
	,, 900. Beck's Achromatic Condenser, with Blue Glass or Iris Diaphragm..	3 0 0			
	Magnifying Power from 54 to 880.		**17**	**16**	**0**

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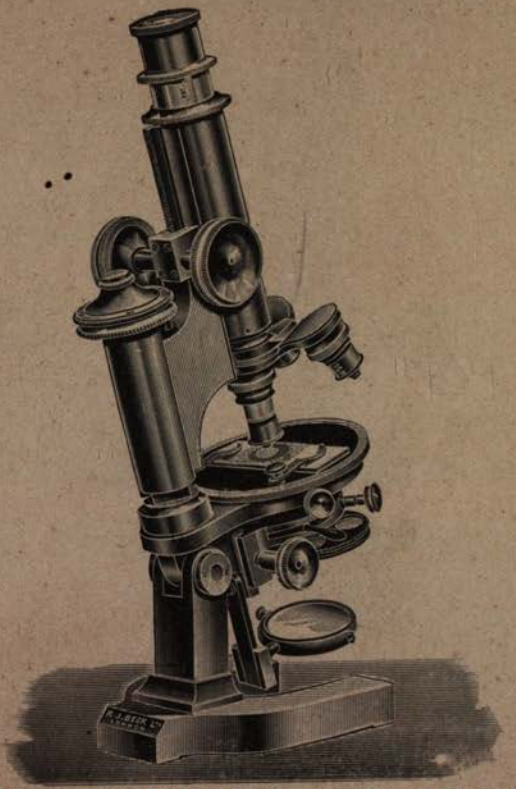
BECK'S MICROSCOPES



No. 51.—THE "CONTINENTAL MODEL" MICROSCOPE.

This is our latest model of Bacteriological Microscope with Centring and Rotating Stage. It has a Nickel Plated Draw Tube engraved in mm. Scale to show length of Mechanical Tube in use. The Spiral Rack and Pinion Coarse Adjustment, and the Micrometer Screw Fine Adjustment are made upon the most approved methods, and a graduated Milled Head is provided for reading the depth of an object, etc. The Spiral Rack and Pinion Focussing Substage and Screw Centring Apparatus are very carefully adjusted to the Stand. The Double Mirror is adjustable on the Swinging Arm. The whole Instrument is finished in the very best style, and is packed in a polished mahogany case, with lock and key and handle.

No.		£	s.	d.
50	**STAND ONLY,** no Object Glasses, no Eyepieces, no Condenser, in Mahogany Cabinet ..		7 15	0
51K	**STAND AS ABOVE**	£7 15 0		
	No. 364. 2 Eyepieces, Nos. I. and II.	0 10 0		
	„ 823. ⅔ inch (16 mm.) Object Glass	1 5 0		
	„ 826. ⅙ inch (4 mm.) do. with Correction Collar ..	2 15 0		
	„ 911. Abbé Condenser, with Iris Diaphragm	1 15 0		
	Magnifying Power from 34 to 400.		14 0	0
51M	**STAND AS ABOVE**	£7 15 0		
	No. 364. 2 Eyepieces, No. I. and II.	0 10 0		
	„ 822. 1 inch (22 mm.) Object Glass	1 5 0		
	„ 825. ¼ inch (6 mm.) do., with Correction Collar ..	2 0 0		
	„ 830. 1-12 inch (2 mm.) Oil Immersion	5 10 0		
	„ 902. Abbé Condenser, with Iris Diaphragm	4 0 0		
	„ 392.* Double Nosepiece	0 12 6		
	Magnifying Power from 38·5 to 880.		21 12	6
51Q	**STAND AS ABOVE**	£7 15 0		
	No. 399. 3 Eyepieces, Nos. I., II. and III.	1 4 0		
	„ 820. 2 inch (40 mm.) Object Glass	1 0 0		
	„ 822. 1 inch (22 mm.) do.	1 5 0		
	„ 824. ½ inch (12 mm.) do.	1 10 0		
	„ 825. ¼ inch (6 mm.) do. with Correction Collar ..	2 0 0		
	„ 827. ⅛ inch (3 mm.) do. do. ..	3 10 0		
	„ 830. 1-12 inch (2 mm.) do. Oil Immersion	5 10 0		
	„ 903. Beck's Achromatic Condenser, with Blue Glass and Iris Diaphragm and series of Patch Stops	5 5 0		
	„ 192.* Triple Nosepiece	1 4 0		
	„ 384. Polarizing Apparatus	1 15 0		
	Nos. 346 and 349. Eyepiece and Stage Micrometers	1 10 0		
	No. 340. Beck's Vertical Camera Lucida	0 18 0		
	Magnifying Power from 16 to 1650.		34 6	0

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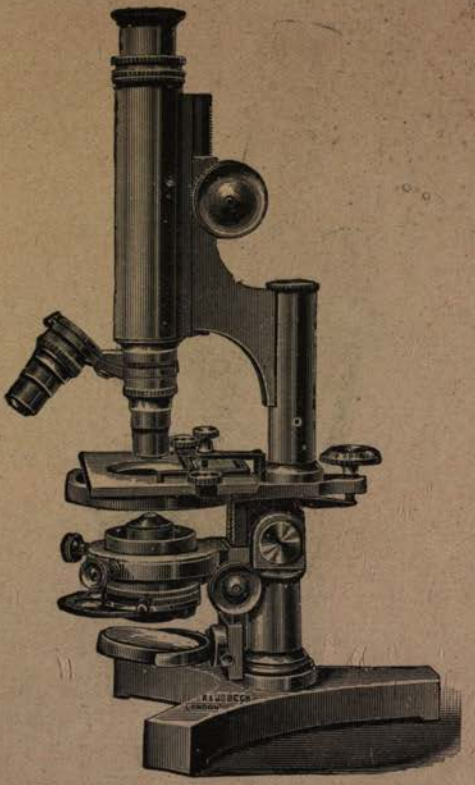
BECK'S MICROSCOPES



No. 20.—THE "PATHOLOGICAL" MICROSCOPE.

This Instrument is one of the very best for all advanced work in Physiology and Pathology; has joint for inclination and a heavy foot which ensures absolute stability in every position. It has Spiral Rack and Pinion Coarse Adjustment, Delicate Lever Fine Adjustment by Graduated Micrometer Screw and Milled Head, Draw Tube, Glass Stage, working under an Adjustable Ivory Point, which in many cases is an excellent substitute for the Mechanical Stage; Spiral Rack and Pinion Focussing Substage with Screw Centring Adjustments, and Double Mirror adjustable on Sliding Bar. The whole packs into a polished mahogany case.

No.			£ s. d.
20	**STAND,** without Condenser, Object Glasses or Eyepieces, in Mahogany Cabinet		**8 15 0**
20K	**STAND AS ABOVE**	£8 15 0	
	No. 399. 2 Eyepieces, No. I. and II.	0 16 0	
	,, 802. ⅔ inch (14 mm) Object Glass	0 12 0	
	,, 804. ⅓ inch (4 mm.) do.	1 10 0	
	,, 911 Abbé Condenser with Iris Diaphragm	1 15 0	
	Magnifying Power from 54 to 400.		**13 8 0**
20P	**STAND AS ABOVE**	£8 15 0	
	No. 399. 2 Eyepieces, Nos. I. and II.	0 16 0	
	,, 822. 1 inch (22 mm.) Object Glass	1 5 0	
	,, 824. ½ inch (12 mm) do.	1 10 0	
	,, 826. ⅛ inch (4 mm.) do. with Correction Collar ..	2 15 0	
	,, 830. 1-12 inch (2 mm.) Oil Immersion Object Glass	5 10 0	
	,, 192.* Triple Nosepiece..	1 4 0	
	,, 902. Beck's Achromatic Condenser, with Blue Glass and Iris Diaphragm	4 0 0	
	Magnifying Power from 38·5 to 880.		**25 15 0**
20Q	**STAND AS ABOVE**	£8 15 0	
	No. 399. 3 Eyepieces, Nos. I, II. and III.	1 4 0	
	,, 820. 2 inch (40 mm.) Object Glass	1 0 0	
	,, 822. 1 inch (22 mm.) do.	1 5 0	
	,, 824. ½ inch (12 mm) do.	1 10 0	
	,, 825. ¼ inch (6 mm) do. with Correction Collar ..	2 0 0	
	,, 827. ⅛ inch (3 mm.) do. do. do. ..	3 10 0	
	,, 830. 1-12 inch (2 mm) do. Oil Immersion	5 10 0	
	,, 903. Beck's Achromatic Condenser, with Blue Glass and Iris Diaphragm and series of Patch Stops	5 5 0	
	,, 192.* Triple Nosepiece..	1 4 0	
	,, 384. Polarizing Apparatus	1 15 0	
	Nos. 346 & 349. Eyepiece and Stage Micrometers	1 10 0	
	No. 340. Vertical Camera Lucida	0 18 0	
	Magnifying Power from 16 to 1650.		**35 6 0**

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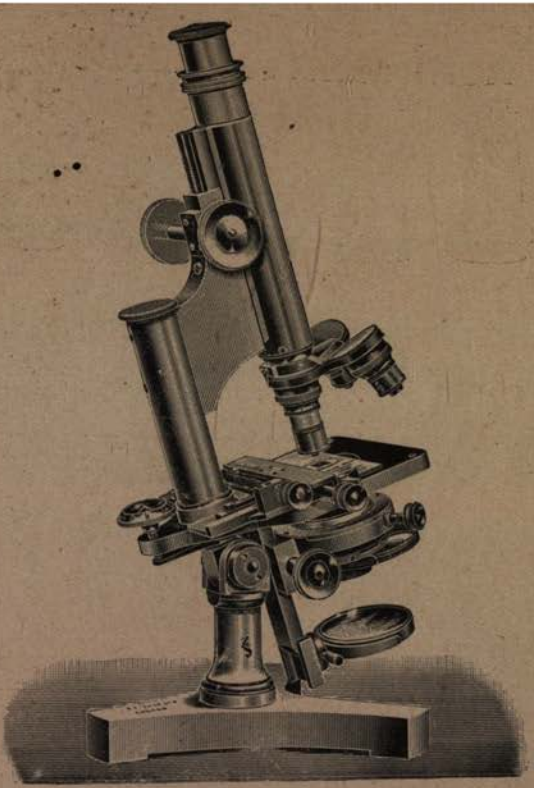
BECK'S MICROSCOPES



No. 17.—THE "PATHOLOGICAL" MICROSCOPE.

The construction of this Instrument is almost identical with that of our No. 20 (the previous fig. on opposite page), with the exception that the Glass Stage is substituted by a large Square Stage, and to this is fitted a Removable Mechanical Stage of the very latest and best construction. The Stand is exceedingly steady in every position, the adjustments are perfect, and we can thoroughly recommend it as the very best Instrument for all high-power work. The Instrument packs into a polished mahogany case, with lock and key and handle.

No.		£	s.	d.
17	**STAND,** with Removable Mechanical Topstage, without Condenser, Object Glasses or Eyepieces, in Mahogany Cabinet	12	5	0
17K	**STAND AS ABOVE** £12 5 0			
	No. 399. 2 Eyepieces, Nos. I. and II. 0 16 0			
	,, 823. ⅔ inch (16 mm.) Object Glass 1 5 0			
	,, 826. ⅙ inch (4 mm.) do., with Collar Adjustment 2 15 0			
	,, 911. Abbé Condenser, with Iris Diaphragm 1 15 0			
	Magnifying Power from 54 to 400.	18	16	0
17P	**STAND AS ABOVE** £12 5 0			
	No. 399. 2 Eyepieces, Nos. I. and II. 0 16 0			
	,, 822. 1 inch (22 mm.) Object Glass 1 5 0			
	,, 824. ½ inch (16 mm.) do. 1 10 0			
	,, 826. ⅙ inch (4 mm.) do., with Collar Adjustment 2 15 0			
	,, 830. 1-12 inch (2 mm.) Oil Immersion Object Glass 5 10 0			
	,, 192.* Triple Nosepiece 1 4 0			
	,, 902. Beck's Achromatic Condenser, with Blue Glass and Iris Diaphragm 4 0 0			
	Magnifying Power from 38·5 to 880.	29	5	0
17Q	**STAND AS ABOVE** £12 5 0			
	No. 399. 3 Eyepieces, Nos. I., II. and III. 1 4 0			
	,, 820. 2 inch (40 mm.) Object Glass 1 0 0			
	,, 822. 1 inch (22 mm.) do. 1 5 0			
	,, 824. ½ inch (12 mm.) do. 1 10 0			
	,, 825 ¼ inch (6 mm.) do., with Collar Adjustment 2 0 0			
	,, 827. ⅛ inch (3 mm.) do. 3 10 0			
	,, 830. 1-12 inch (2 mm.) Oil immersion 5 10 0			
	,, 903. Beck's Achromatic Condenser, with Blue Glass Diaphragm and Patch Stops 5 5 0			
	,, 192.* Triple Nosepiece 1 4 0			
	,, 384. Polarizing Apparatus 1 15 0			
	Nos. 346 and 349. Eyepiece and Stage Micrometer 1 10 0			
	No. 340. Vertical Camera Lucida 0 18 0			
	Magnifying Power from 16 to 1650.	38	16	0

R. & J. BECK, LTD., 68, CORNHILL, LONDON.

BECK'S ACHROMATIC OBJECT GLASSES.

Series A.

Cat. No.	Focal Length in Millimetres.	English Designation.	Angular Aperture.	Numerical Aperture.	Approximate Magnifying Powers. 160 mm. 6¼ inch, length of body. Eyepieces. 1	2	3	200 mm. 8 inch, length of body. Eyepieces. 1	2	3	Price. £ s. d.
800	40 mm	2 inch	7°	0·06	16	24	45	21	32	61	0 15 0
801	22 ,,	1 ,,	15°	0·13	38·5	59	111	49	74	140	0 12 0
802	14 ,,	⅔ ,,	17°	0·15	54	82	152	68	100	192	0 12 0
802a	12 ,,	½ ,,	35°	0·30	80	120	225	100	150	280	1 5 0
803	6 ,,	¼ ,,	85°	0·68	147	220	420	183	270	510	1 1 0
804	4 ,,	⅙ ,,	90°	0·71	216	328	620	270	400	760	1 10 0
805	3 ,,	⅛ ,,	110°	0·82	290	430	820	360	530	1000	2 0 0
Homogeneous Oil Immersion.											
810	2 ,,	1/12 ,,	—	1·N.A.	480	720	1360	590	880	1650	4 0 0

1-12 Inch Oil Immersion, Price £4,

Is as perfect a Lens as we can make. It possesses only a moderate aperture, but for histological work this, in giving greater penetration, is an advantage.

Series B.

Cat. No.	Focal Length in Millimetres.	English Designation.	Angular Aperture.	Numerical Aperture.	Approximate Magnifying Powers. 160 mm. 6¼ inch, length of body. Eyepieces. 1	2	3	200 mm. 8 inch, length of body. Eyepieces. 1	2	3	Price. £ s. d
820	40 mm.	2 inch	8°	0·07	16	24	45	21	32	61	1 0 0
821	30 ,,	1½ ,,	15°	0·13	21	33	61	28	42	80	1 5 0
822	22 ,,	1 ,,	18°	0·16	36	55	106	46	70	133	1 5 0
823	16 ,,	⅔ ,,	20°	0·18	49	75	140	63	93	176	1 5 0
824	12 ,,	½ ,,	38°	0·33	80	120	225	100	150	280	1 10 0
825	6 ,,	¼ ,,	85°	0·68	147	220	420	183	270	510	2 0 0
826	4 ,,	1/6 ,,	110°	0·82	216	328	620	270	400	760	2 15 0
827	3 ,,	⅛ ,,	110°	0·82	290	430	820	360	530	1000	3 10 0
Homogeneous Oil Immersion.											
830	2 ,,	1/12 ,,	—	1·25	480	720	1360	590	880	1650	5 10 0
831	1·5 ,,	1/16 ,,	—	1·25	640	960	1810	780	1180	2200	9 0 0

Nos. 825, 826 and 827 have Correction Collars. The Object Glasses which do not have a Correction Collar are adjusted for cover glass ·006 inches (·15 mm.) thick. They are all supplied in Brass Boxes, and many of the powers are approximately the required lengths to focus with a Double Nosepiece.

R. & J. BECK, LTD., 68, CORNHILL, LONDON.

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